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ABSTRACT

Several aspects of system interconnections are treated in this report. The interconnection of existing and future cable television (CATV) systems for two-way transfer of audio/video and digital data signals is surveyed. The concept of interconnection is explored relative to existing and proposed CATV systems and broadband teleservice networks, common carrier services, facilities and growth projections, and the technical-economic state-of-the-art of the required technology. The need for interconnection is reviewed. Satellite and line-of-sight microwave transmission in addition to digital versus analog transmission systems aspects are considered in terms of interconnection. Lastly, some potentially significant queueing problems are identified. (Author)

OT REPORT 73-13

A SURVEY OF TECHNICAL REQUIREMENTS FOR BROADBAND CABLE TELESERVICES VOLUME 5

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

OT

U.S. DEPARTMENT OF COMMERCE/Office of Telecommunications

VOLUME 5
SYSTEM INTERCONNECTIONS

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U.S. DEPARTMENT OF COMMERCE
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July 1973

UNITED STATES DEPARTMENT OF COMMERCE

OFFICE OF TELECOMMUNICATIONS

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Conducts research needed in the evaluation and development of telecommunications policy as required by the Office of Telecommunications Policy, Executive Office of the President, pursuant to Executive Order 11556;

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Conducts research, engineering, and anlaysis in the general field of telecommunication sciences to meet government concerns;

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FOREWORD

As information transfer becomes more important to all levels of society, a number of new telecommunication services to homes and between institutions will be required. Many of these services may require broadband transmission. The new services may, in part, evolve from those provided by cable television.

This is one of a series of reports resulting from a survey of the CATV industry and related technological industries. The survey identifies some of the important technical factors which need to be considered in order to successfully bring about the transition from the technical state of today's cable television and services to those new teleservices which seem to be possible in the future.

The current and future broadband capabilities of telephone networks are not discussed since they are described in many Bell Laboratory and other telephone company publications. Also, the tremendous load projected for common carrier telephone and data systems in voice and data communication suggests that two-way, interactive, broadband networks, not now in existence, may be required in addition to an expanded telephone network. The many aspects of economic viability, regulation, social demand, and other factors that must be considered before the expectation of

the new teleservices can be fulfilled are not within the scope of these reports. These reports concentrate on technical factors, not because they are most important, but because they have been less considered.

A report about the state-of-the-art and projections of future requirements in a complete technology draws material from a vast number of sources. While many of these are referenced in the text, much information has been obtained in discussions with operators, manufacturers, and consulting engineers in the CATV industry. Members of the National Cable Television Association, particularly, have been most helpful in providing information, discussing various technical problems, and in reviewing these reports.

Because of the substantial amount of material to be discussed it was believed most desirable to present a series of reports. Each individual report pertains to a sub-element of the total system. However, since some technical factors are common to more than one sub-component of the system, a reader of all the reports will recognize a degree of redundancy in the material presented. This is necessary to make each report complete for its own purpose.

The title of the report series is: A Survey of Technical Requirements for Broadband Cable Teleservices. The seven volumes in the series will carry a common report

number: OTR 73-13. The individual reports in the series are sub-titled as:

A Summary of Technical Problems Associated with Broadband Cable Teleservices Development, OT Report No. 73-13, Volume 1.

Subscriber Terminals and Network Interface, OT Report No. 73-13, Volume 2.

Signal Transmission and Delivery Between Head-End and Subscriber Terminals, OT Report No. 73-13, Volume 3.

System Control Facilities: Head-ends and Central Processors, OT Report No. 73-13, Volume 4.

System Interconnections, OT Report No. 73-13, Volume 5.

The Use of Computers in CATV Two-Way Communication Systems, OT Report No. 73-13, Volume 6.

A Selected Bibliography, OT Report No. 73-13, Volume 7.

W.F. Utlaut
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SYSTEM INTERCONNECTIONS

Peter M. McManamon*

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Key words: CATV, Cable TV, Interconnection, Common Carrier Services, Teleservices, Satellite Television Distribution, Broadband Cable System Queueing

1. INTRODUCTION

The traditional franchised CATV system is viewed as a telecommunication entity in this survey. Independent of its internal configuration as a tree, star, or loop network, this individual CATV system entity may or may not interconnect with similar geographically adjacent entities or with geographically non-adjacent CATV systems through an

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interconnection network. An interconnection network is defined as a broadband telecommunications network which provides CATV systems with the means to collect information signals from other CATV systems or other sources or to distribute information to other CATV systems or users.

CATV systems originated in response to a need for over-the-air connection to the television broadcast stations and networks for a variety of reasons, including adverse propagation conditions. The CATV head-end was connected to both local and distant television stations and FM radio stations as well as the national broadcast networks. The methods of connection include off-the-air direct reception, coaxial cable relay, and microwave radio relay. The service traditionally has been one-way distribution of entertainment television and FM radio. More recently some local program origination has been provided as well as education and public affairs programs. One-way distribution of CATV programs originated by the CATV system to other CATV systems is viewed as a form of interconnection. Two-way services are still largely in the speculative or experimental stages. With two-way services, interconnection needs also arise.

Rheinfelder (1970) gives a thorough introduction to many aspects related to CATV systems. Sackman and Boehm (1972), Martin (1971), and Baer (1971) are among many authors who

discuss aspects of two-way systems and proposed or planned services to be offered. Shapiro's (1972) doctoral thesis considers many aspects of system interconnection in studying networking in the industry. In addition, the bibliography mentioned in the foreword provides numerous other references.

Finally, it is desirable to note the relevant current activities of the panels of the FCC Cable Television Advisory Committee (C-TAC). This committee has active participation of the CATV industry and many related industries. Panel 7 of the Committee is particularly concerned with matters relating to system interconnection and interface capability.

This report reviews existing connections and interconnections as an introduction to the needs and concepts of CATV system interconnection. The report cannot be considered as comprehensive because of the scope of the subject. Systems and technology required to accomplish this interconnection are discussed. The starting point is a summary of interconnection problems and needs, particularly as they relate to the growth of the CATV industry. Unavoidably this summary assumes some of the background given in subsequent sections.

2. SUMMARY AND RECOMMENDATIONS

CATV systems grew out of a need for improved reception of television broadcasts. This chapter is concerned with CATV system interconnection in the larger view of broadband telecommunication connections which include but are not limited to television. Interconnection can be on a metropolitan, regional, national, or international basis. The development of many proposed services, including a partial substitution of telecommunications for travel, have the long term potential of needing hundreds of television channels within communities of as few as 30,000 subscribers. The results of a queueing analysis discussed in section 5.4 suggests such a possibility. With such demand for television channels in a CATV system, the need for extensive interconnection regionally or nationally may not be as great as some forecasts suggest.

On the other hand, many services proposed (including partial substitution of telecommunications for travel) may require extensive regional and national interconnection in order to be implemented in the near future. The systems will necessitate large computer systems and software development and correspondingly large amounts of investment capital. Once established and proven, the services would begin to be implemented locally.

The current problem is the lack of complete system designs, cost estimates, and performance evaluations for implementation of most proposed two-way services. Certain parts of each system would have to be implemented in order to develop engineering-economic data for performance analysis. System designs would not have to be developed for all services immediately. It would be a significant contribution to work out the details of even one of the proposed services. System designs published by others (Mason et al., 1972; Baer, 1971) provide good starting points, but are inadequate in design detail. Performance and cost estimates are difficult to develop without such design details although some authors (Sackman and Boehm, 1972) do give cost and performance estimates without extensive system design details. System designs with experimental demonstration of new equipments required may improve the climate for capital investment since the "research and development" risks would be substantially lessened. Additional investment considerations are discussed by Park (1972) and McGowan, et al. (1971).

A secondary aspect of the system design problems concerns the local telephone switched system. As reviewed in table 9, many proposed services could be implemented through regional interconnection using the existing

telephone system. Commercially available terminals can be interconnected through Data Access Arrangements. The touch-tone telephone has numerous potential applications which provide many of the proposed services as described by Martin (1971). A number of unanswered questions arise:

a) Which of the services proposed are better suited to the switched telephone network?

b) Why are these services not being marketed at the present time, using existing terminals, computers, and the telephone system?

c) What would be the effect on top 100 market penetration by CATV systems if aggressive common carrier competition developed for some of the proposed CATV system services?

The second major problem concerns the existing telecommunications capacity in the United States for support of CATV broadband signal interconnection. The possible rates of growth in view of the demands for other services is a problem. The AT&T projections for their voice and data common carrier network growth to meet 1980 demands is over 3,000,000 new channel miles (section 3). The present 1,180,000 channel mile microwave network is only one-third of the projected 1980 network. Two-thirds of the required new network must be constructed.

Projections for terrestrial, specialized data, common carriers suggest little if any excess capacity for CATV interconnection. The large bandwidth radio and waveguide transmission systems are largely in the research and development cycle. The Canadian and U.S. Domestic Satellite systems as launched or proposed total over 624 transponders in synchronous orbit. Each transponder can relay one color television broadcast quality signal. These systems generally use the 4 GHz and 6 GHz terrestrial common carrier transmission bands and have to operate at reduced radiated power levels to avoid interference. The effect of operating at reduced power levels is an increased cost of transmit/receive and receive-only ground terminals ($200,000 and $100,000, respectively). Further, the ground terminals must be located away from existing microwave links (see figure 4). New microwave links will be needed to interconnect the earth terminals with the CATV systems. Projections of CATV interconnection system needs to determine if sufficient capacity will be available or is being planned for future development does not appear to have been published. If the information does exist in one place, it is not readily available.

The third major problem area in CATV system interconnection involves the cost projections for regional

or national distribution. Distribution costs by terrestrial microwave and satellite are shown to be within the same order of magnitude (see sec. 3). Costs on the order of \$1.00 to \$2.00 per month per subscriber are estimated for 25 program hours per week and 110 CATV systems. Good economic estimates are not available for substantially larger networks and increased program hours per week, but it would be difficult to reduce costs of one-way television distribution below \$0.25 per subscriber per month for a 10,000 subscriber CATV system. Basically some engineering cost projections and analysis must be developed. They must be based on well-defined services in order to carefully estimate the network scheduling and administrative costs and the equipment needed at the CATV system head-end. The system designs mentioned previously would be needed here.

Some indications are developed in section 3.3 which suggest that CATV systems must develop an aggregation of services available through a multipurpose terminal. Such a terminal has yet to be designed. This approach involves a need for video and data interconnections of a variety usually available only from a common carrier.

Direct satellite-to-the-home television broadcast still faces technical limitations, but most of the present limitations are economic. Because of these limitations,

CATV systems become one of a number of reception centers for satellite television distribution. One-way and two-way services via satellite in the next five years will be influenced strongly by the domestic satellite systems proposed and the ATS-F educational television experiment. The Canadian Domestic Satellite ANIK I is operational, with ANIK II to be launched in the spring of 1973. Up to twelve television channels apparently will be leased to U.S. companies for one to two years. These channels could have a significant impact on CATV television distribution through interconnection by providing long distance facilities during 1973 without large terrestrial microwave network construction. The next planned NASA satellite launch associated with CATV systems will be the ATS-F Educational Television Broadcast one-year experiment in the Rocky Mountain area scheduled for the spring of 1974.

The Canadian Technology Satellite to be launched by NASA in 1975 will investigate the feasibility of direct satellite data, voice, and television broadcast to receive only terminals in the 10 GHz band. The U.S. Domestic Satellite systems have proposed a total of over 600 transponders in synchronous orbit (one color television channel each), although the number and dates of launch for each system are yet to be determined. Launches before late 1974 would

represent a rapid development program. The U. S. Domestic Satellites will have an impact on CATV interconnection, but it is difficult to estimate without further study.

For future development, it is recommended that a program be developed to investigate the feasibility of inexpensive earth terminals operating in frequency bands above 10 GHz. Operation at these frequencies is not faced with as many international and national restrictions, particularly relative to satellite radiated power flux density. It is also recommended that digital television techniques be given serious consideration in such an investigation.

Terrestrial microwave systems of the FDM/FM common carrier type have well known performance characteristics (table 2). Three current EIA standards, RS-250-A, RS-252-A, and RS-240, provide information on standards for television relay and microwave transmission systems as well as the standards for television broadcast transmitters. (EIA, 1961, 1967, and 1972). The relay standards RS-250-A includes many parameters related to interface requirements with microwave equipment. Determination of any interface compatibility problems between microwave relay and cable systems would require further study. In addition, recent developments in linear microwave power amplifier design should be exploited. This

development could have an impact in replacing wide bandwidth, high index, FDM-FM with narrow-bandwidth SSB-AM.

Current research in video picture coding of broadcast quality signals has established the feasibility of a 4.1×10^6 bps data rate per channel when groups of 12 to 15 black and white Picturephone* channels are multiplexed. With about 19 to 20 dB signal-to-noise ratios, eight level coherent PSK modulation ideally could be used to transmit this data rate in bandwidth of 1.4 MHz to 2.8 MHz at a bit error rate of 1×10^{-6}. This indicates the potential for transmission of more than one digital television channel in the present 6 MHz analog channel bandwidth. Further, a single cable may be able to carry up to 80 digital television channels. These rates, however, begin to approach practical coaxial cable limits as Pierce (1966) has shown. The signal-to-noise ratios are over 20 dB below that presently required in the CATV interconnection and trunk circuits. A trade-off may exist in the required number of amplifiers versus the required digital equipment. The latter would be substantial, though, with present technology.

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Investigation of digital picture coding and transmission techniques would be recommended. Digital data networks may provide a suitable short term interconnection network. Operation with computer-communication networks may be feasible for some applications. The present ARPA computer network could be used for demonstration of feasibility and potential. Interaction between CATV systems and computer-communications networks could have the potential of creating a new source of one-way animated graphics and two-way interactive programs for CATV system use.

In addition to the above, a primary problem will concern the development of major services during the next few years. A major development must occur in new forms of one-way <u>entertainment</u> video materials and new sources of supply. Almost all two-way services projected will require <u>extensive</u> software development, computer networks, <u>major consumer education</u> in interactive communications, and extensive data transmission experience. Even if low cost home terminals and national networks are developed, these problems must be resolved for profitable two-way services.

Finally, data transmissions by institutions, companies, and some homes may grow too fast for local telephone central office growth. Most specialized common carriers plan to rely on telephone common carriers for local connection for

their network service thereby creating additional loads on telephone central offices. CATV opportunists may be able to capitalize on this. The CATV operators would have to provide a metropolitan data service with interconnection to common carrier facilities (Milne, 1972).

3. THE CONCEPT OF INTERCONNECTION

3.1. Franchised CATV Systems

What is a CATV system? Historically, it originated as the combination of a receiving antenna farm, head-end terminal, and miles of coaxial cable. One-way audio/video signals (television programs) were received, sometimes translated in frequency, and distributed to subscribers. The antenna farm was the point of connection by direct line-of-sight radiation to the television broadcast stations. Some of these in turn were connected to the common carrier national broadcast television networks.

As CATV systems develop, distinctions on technical or economic grounds become confused. This is particularly true for many aspects of the multiple service, broadband, two-way networks proposed as future CATV systems. In the current regulatory climate, CATV systems exhibit a characteristic not shared with the broadcast stations, common carriers, or

specialized common carriers. The CATV operator must obtain a franchise from the respective municipal or county government in order to install a system and provide services.

Some exceptions concerning franchising do exist. Rhode Island has a state franchise as opposed to county or municipal. In 1971, telephone companies owned 5.1 percent (132) of the existing CATV systems in the United States. It is not known if all are franchised. Cable systems installed completely on private property or municipally owned systems may be exceptions. Generally speaking, though, local franchises are required for CATV system installations.

The bandwidth available in a cable system has led to considerable speculation concerning the potential services which might be made available. These might be summarized as the distribution, collection, interconnection, sensing, and interactive functions including, but not limited to:

a) Distribution of multiple broadband channels from central facilities to office, home, or institution, possibly on request in both urban and rural areas;

b) Collection of multiple broadband channels from office, home, or institution and transmission to a central facility, possibly on request in both urban and rural areas;

c) Interconnection of public institutions and commercial enterprises with two-way channels of broadband capability carrying a multiplicity of signals;

d) Provision of sensing networks to facilitate management of urban activities;

e) Interconnection of broadband systems via long distance broadband trunk lines or satellite links; and

f) Provision of two-way interactive communications for education, programing, polling, and similar services.

The question of singular importance concerns the rate of growth of locally franchised and interconnected CATV systems towards such broadband telecommunication systems. The rate of growth question is best examined in the context of existing systems and interconnections. Descriptions of numerous systems appear in other reports in this series and in the literature. Rogeness (1971) gives a simple diagram of a CATV system which is used in an illustration of some network aspects of interconnection, as shown in figure 1. Regional groups of CATV systems are indicated in figure 1a without any interconnection shown. Some examples of interconnection networks are given in figure 1c.

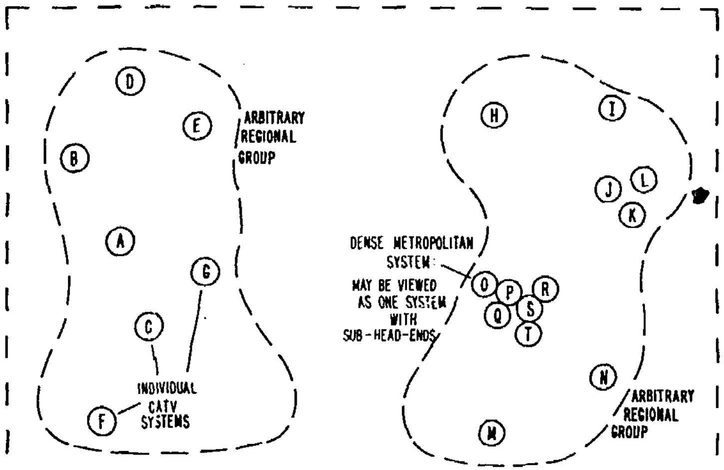

Figure 1a. Regional groups.

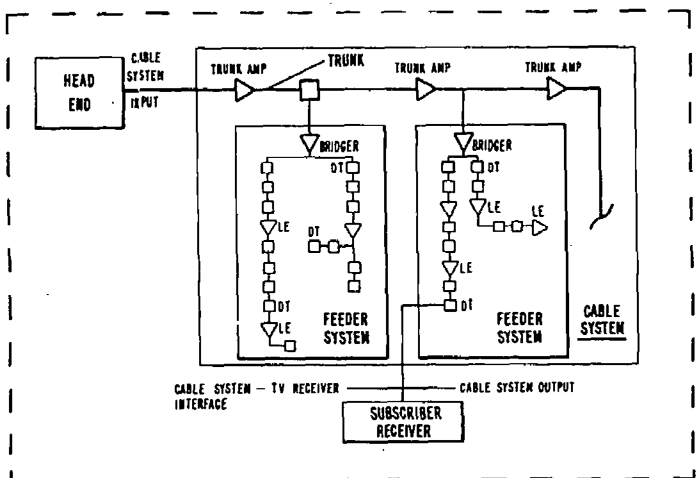

Figure 1b. Typical CATV system (reprinted with permission from the 20th Annual NCTA Convention Official Transcript.

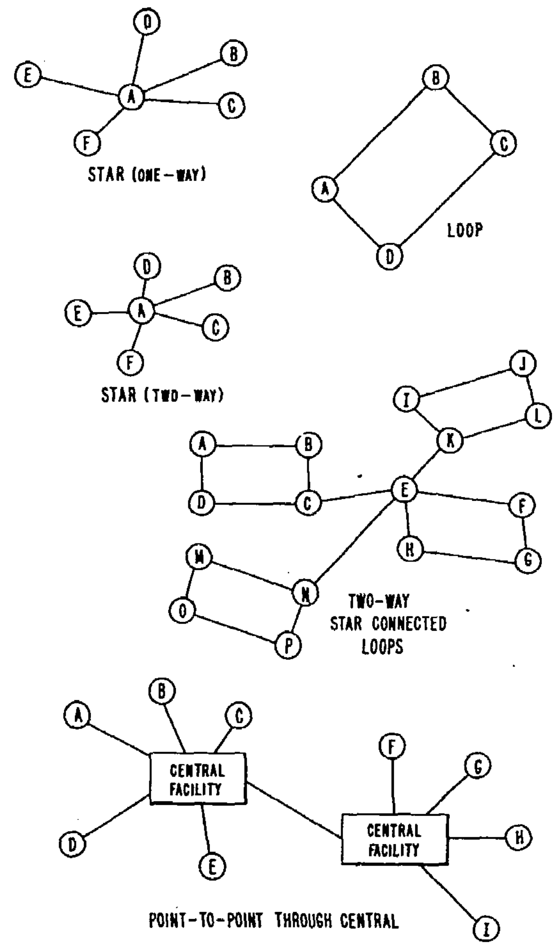

Figure 1c. Some possible network configurations.

In the star (two-way) configuration shown, "A" would have to be a relay center to have full point-to-point service. Otherwise lines from each station to all others must be connected. CATV systems may be connected in loop configurations, and loops may be interconnected with star hierarchies or loop hierarchies. Point-to-point interconnection can be obtained through a central facility, and central facilities can be interconnected in a hierarchy (star, loop, or a series of central layers). Numerous other network interconnection combinations can be visualized by the reader. In all the diagrams, each link could be constructed of terrestrial circuits (cable, microwave, or more advanced techniques) or satellite circuits. A good possibility for a satellite application might be as the central facility.

An important observation can be made about figure 1. Most of the CATV systems which have been interconnected operate with the networks described in section 3.2. No two-way services currently are provided through interconnection. System designs with related performance estimates and costs do not appear in the literature.

3.2. Common Carrier Services and Facilities

Several broadcast networks own small segments of microwave networks. Commercial networks normally contract on a monthly basis for a specified network routing. Special event programs are distributed by hourly leases from the common carrier occasional network. The commercial networks annual cost for long line distribution is usually estimated at $70 to $80 million.

For perspective, it is noted that the Bell System has a network of about 1,180,000 channel miles of broadband capability in the 2, 4, 6, and 11 GHz bands. An additional 100,000 route miles of privately owned microwave radio are installed in the United States. Figure 2 shows the common carrier network in the United States for distribution of the three major network television signals. Unless replaced by satellite distribution, the network will probably continue to serve this purpose during the next few years.

The Public Broadcast Service (P.B.S.) interconnection network network projected for 1975 is shown in figure 3. The dedicated network has 110 stations and operates on a "round robin" or loop basis in the Eastern and Central U.S. Any station on the loop network may receive or originate programs for loop distribution to the network. As noted in figure 3, the entire network consists of the aforementioned

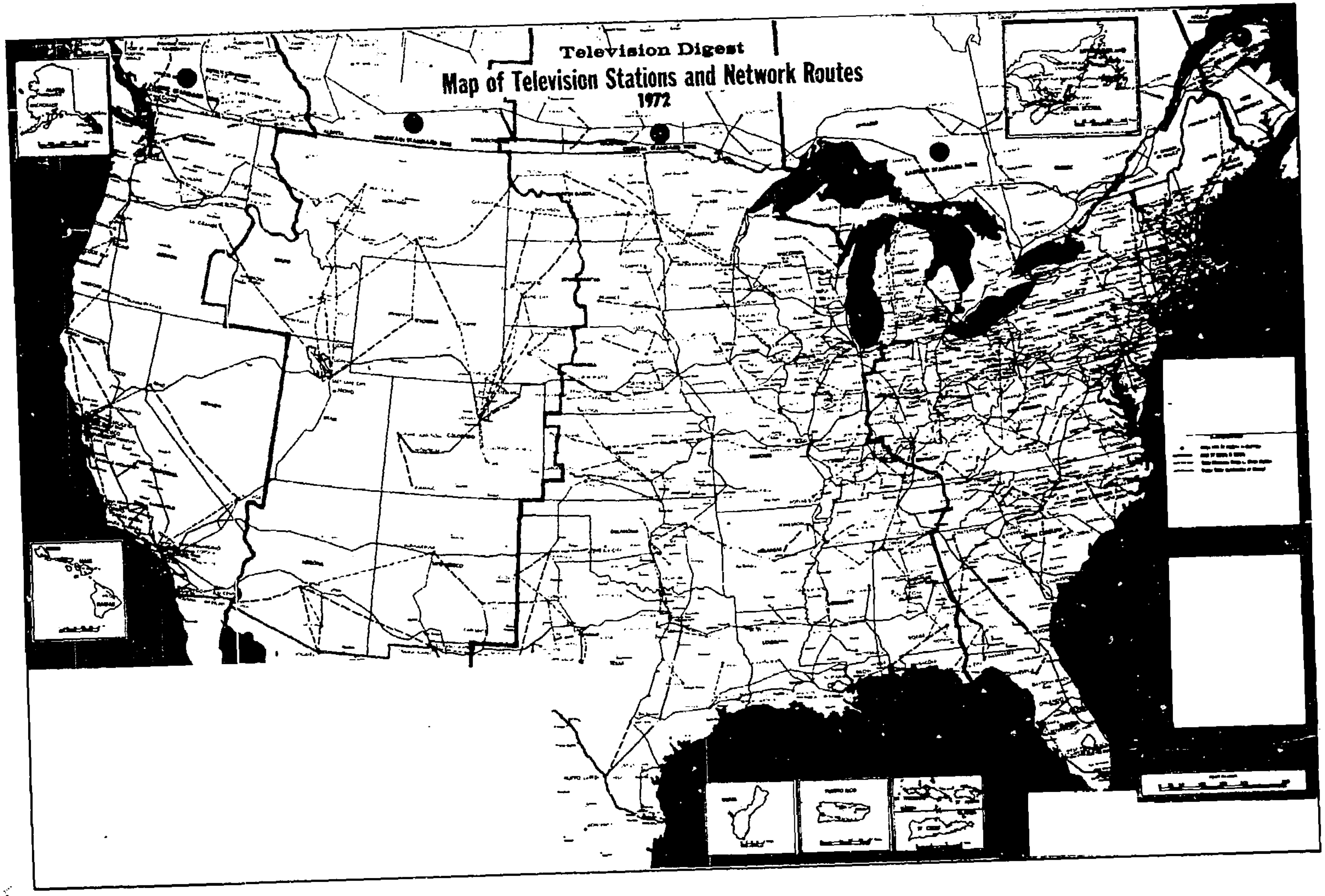

Figure 2. Television network routes (reprinted with permission from Television Digest, 1972).

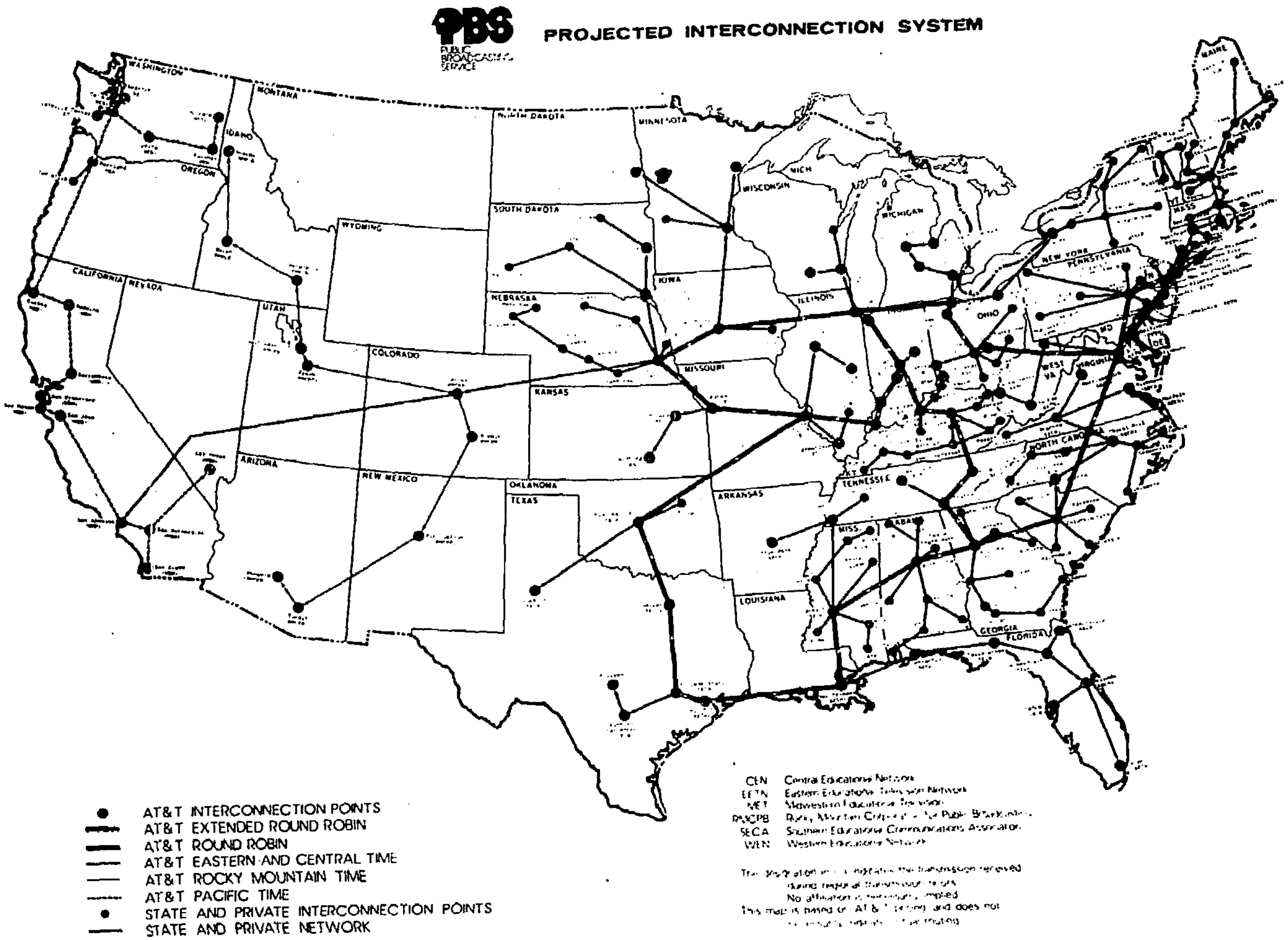

Figure 3. Public Broadcasting Service interconnection system (reprinted with permission from Wells and Bruce, 1972, AIAA paper no. 72-552).

loop with loop stations connected to other stations in various star-tree network one-way combinations.

The primary network annual lease cost will be approximately $5 million in 1975. Because of time zone differences, the majority of the video distribution is done in real time to regional centers and recorded for delayed distribution in the regions. The P.B.S. administrative operating budget for primary distribution was $8 million in 1972. No programing costs are included. Regional centers in Denver and Los Angeles operate at a total annual cost of about $700,000 per year for delayed distribution.

Western Telecommunications, Inc. (WTCI) is a specialized common carrier who owns and operates the network shown in figure 4. Proposed network growth is shown in figure 5. The five market areas of Los Angeles, San Francisco, Portland, Salt Lake City, and Denver can each originate programs for network distribution. The system provides one-way television signal distribution with plans for data and voice service in the future. WTCI currently serves 160 CATV systems, 21 unaffiliated television broadcast stations, as well as all three television networks in certain areas. WTCI provides about 44,000 video channel miles in the area shown in figure 4. The three large circles in figure 4 show provisions for satellite earth terminals.

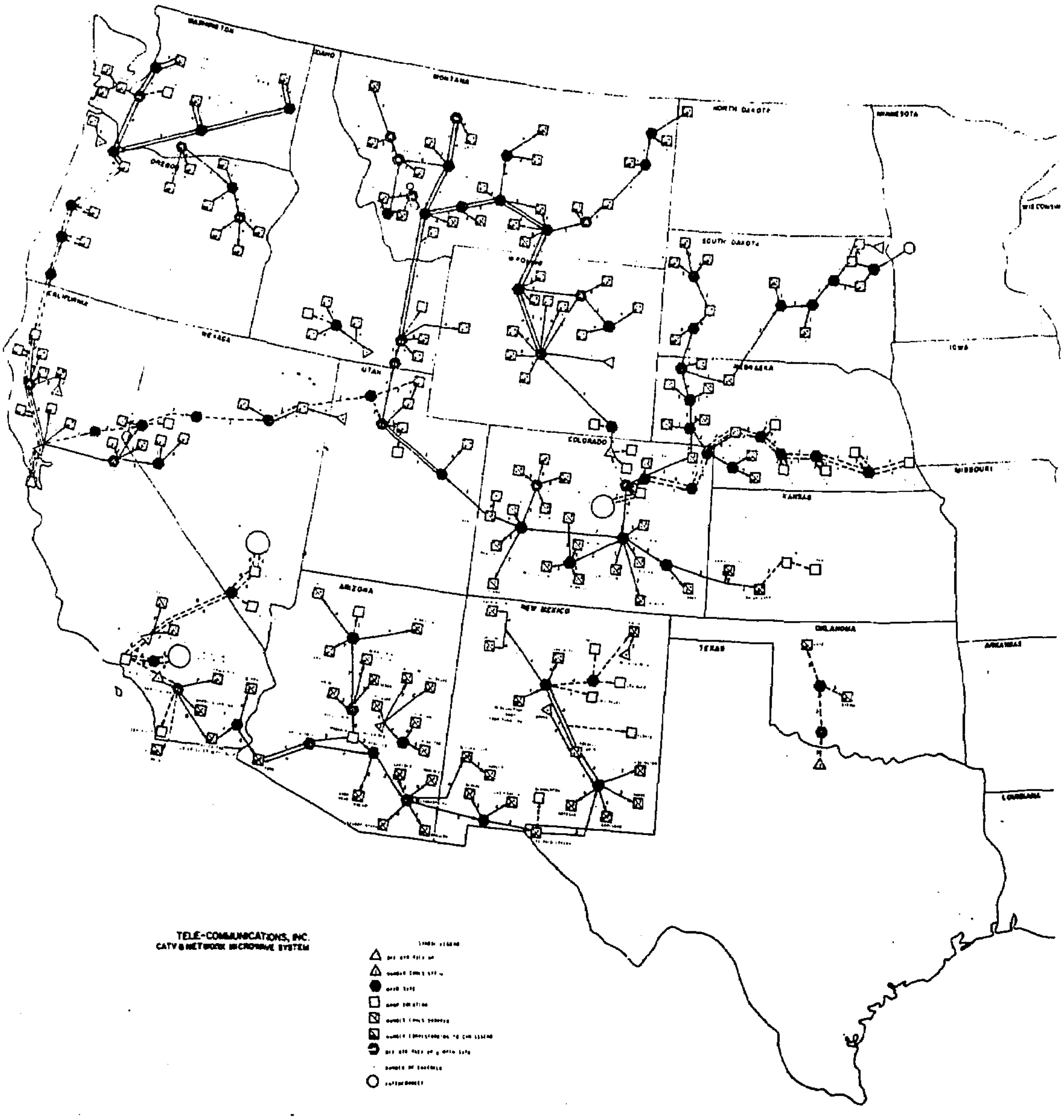

Figure 4. Western Telecommunications Inc. CATV and network microwave system (reprinted with permission from Johnson, 1972, AIAA paper no. 72-557).

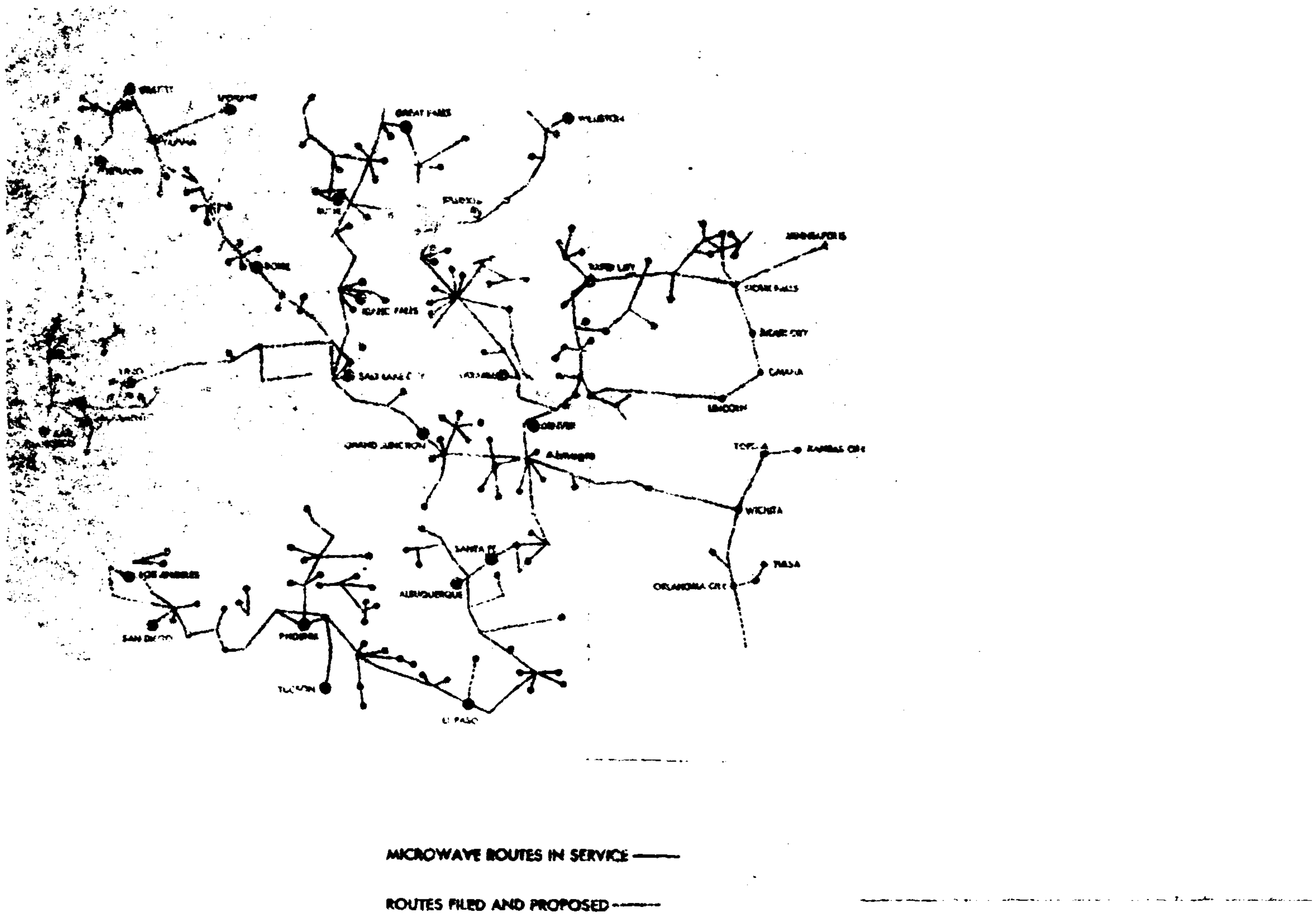

Figure 5. Western Telecommunications, Inc. proposed network microwave systems.

The main trunks use heterodyne to I.F. for amplification and operate in the 4, 6, and 11 GHz bands. Spur connections use baseband amplification with remodulation. Network feeds use space diversity transmission with a hot standby transmitter/receiver system.

WTCI uses route averaging instead of rate averaging (Bell System) for tariffs. In route averaging, the costs and profits associated with each point-to-point route are distributed among the customers served by that route. In the Northwest sector, Bell System tariffs for a 24 hour a day network television feed were $84 per mile per month, with a new proposed rate of $55 per mile per month. Johnson (1972) notes that WTCI's tariff averages $45 per mile per month. Average rates are listed in table 1. The total average capital investment per channel per microwave link is $20,645.

Other specialized microwave common carrier or CATV owned microwave networks in existence or development are exemplified by networks of A.T.C. Corporation of Denver (Minnesota, Wisconsin area); Cable Communications General of Denver; Bill Daniels and Associates of Denver; C.P.I. Corporation of Austin, Texas; N.C.C.C. of Lincoln, Nebraska; and United Video, Inc. of Tulsa, Oklahoma. Time did not permit obtaining network diagrams for these or other networks.

Table 1

WTCI Average Monthly Rate per Television Channel*

Mountain Microwave	$396
American Television Relay	$425
Sierra Microwave	$209
Western Tele-communications	$365
Telecommunications of Washington & Oregon	$230

*Reprinted with permission from Johnson, 1972, AIAA paper no. 72-557

Network geographical diagrams do not illustrate the types of transmission circuits involved or the system in which the particular network operates. For common carrier services and facilities in the United States, these factors are illustrated by considering the system hierarchies involved and the mixture of digital and analog transmissions. The digital versus analog question has numerous parts. In section 5.3 the question of digital television signals is considered. These digital signals may be transmitted using FM analog modulation in an FM network or may be transmitted using digital PSK modulation with either FDM or TDM. Generally, but not always, analog television using FDM-FM is called analog, digital television with FDM-FM is called hybrid, and digital television with TDM-PSK is called digital.

Figure 6 gives an example of the hierarchy of switching centers and the transmission hierarchy. One notes a transmission facility mixture of K carrier (twin paired cables), L coaxial cable, and microwave radio links as well as other carrier types. Figure 7 shows a schematic of the FDM hierarchy used by U.S. common carriers. The L-4 carrier is a 17 MHz bandwidth system using two coaxial tubes and 2 mile repeater spacing. The L-5 carrier has a 57.5 MHz bandwidth using two coaxial tubes and 1 mile repeater

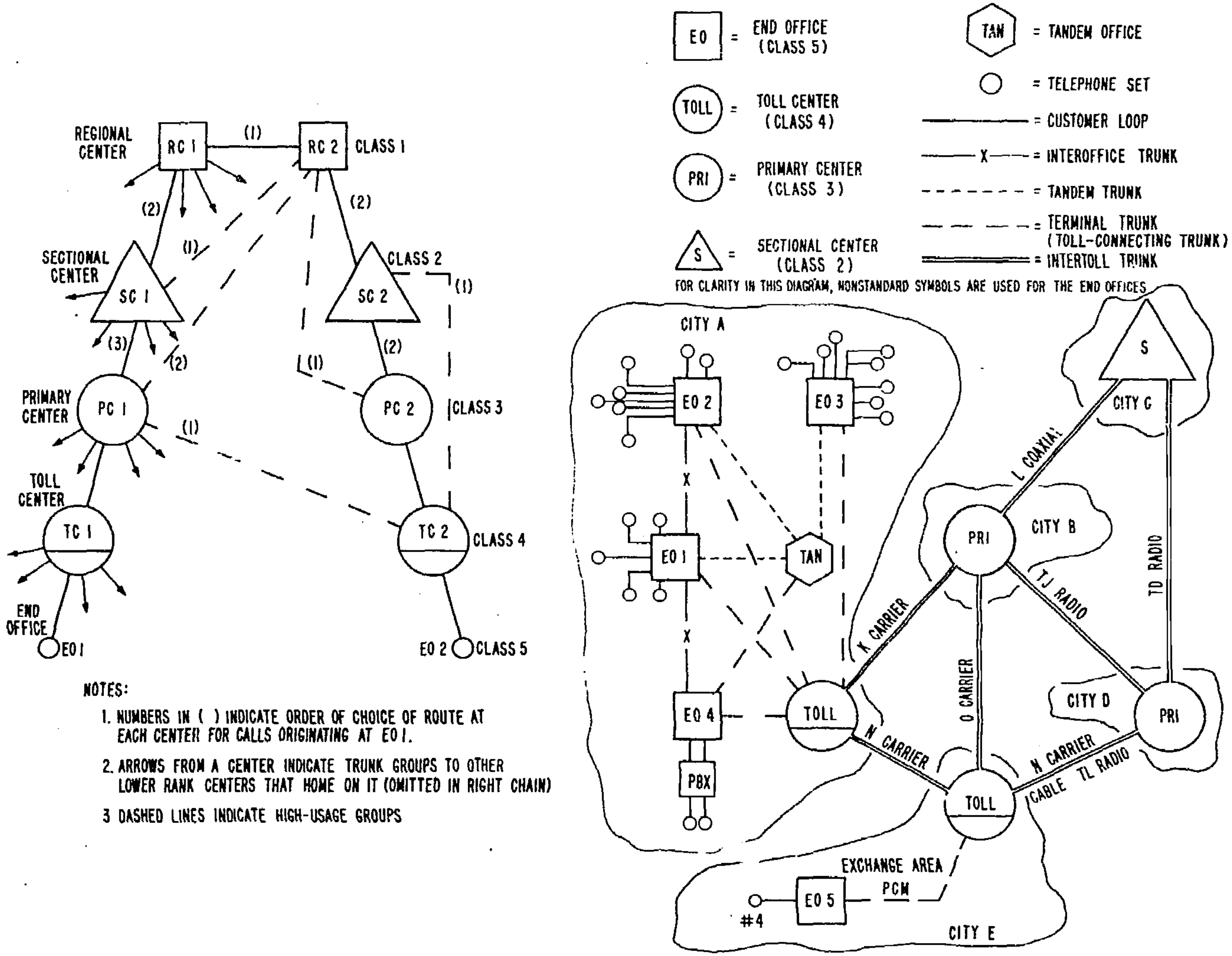

Figure 6. Hierarchy of switching centers and transmission facilities.

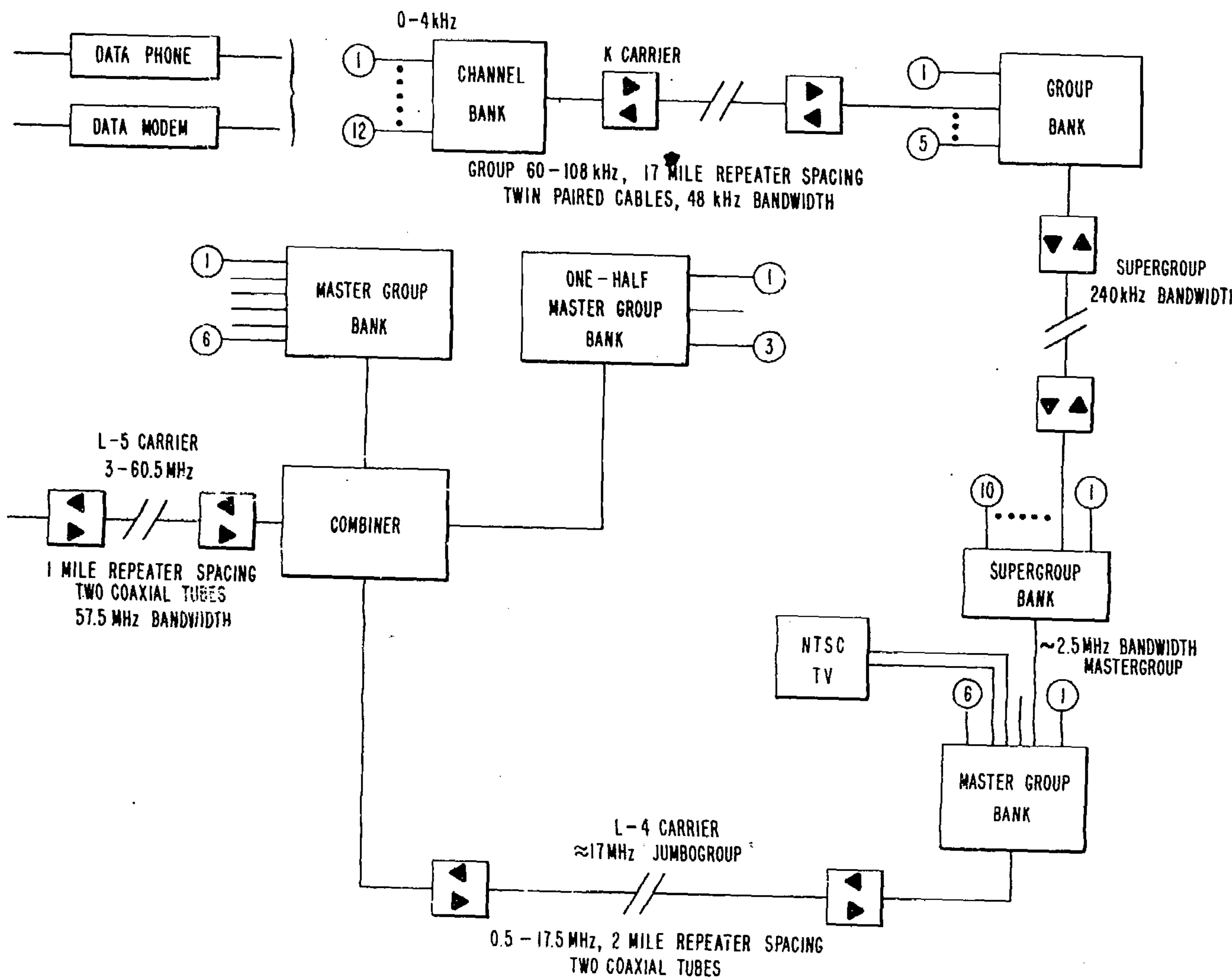

Figure 7. FDM hierarachy - U. S. common carriers.

Table 2
Selected Features of Bell Laboratory Designed Radio Systems

System designation	Band occupied (GHz)	Message circuits per radio channel	Repeater type	Full-duplex radio channels in fully loaded route Working	Protection
TD-2	3.7-4.2	600-1200	i-f	10	2
TD-3		1200	i-f	10	2
TH-1	5.925-6.425	1800	i-f	6	2
TH-3		1800	i-f	6	2
TM-1		600-900	BSB	4*	4*
TJ	10.7-11.7	600	BSB	3*	3*
TL-1		240	BSB	3	3
TL-2		600-900	BSB	3*	3*

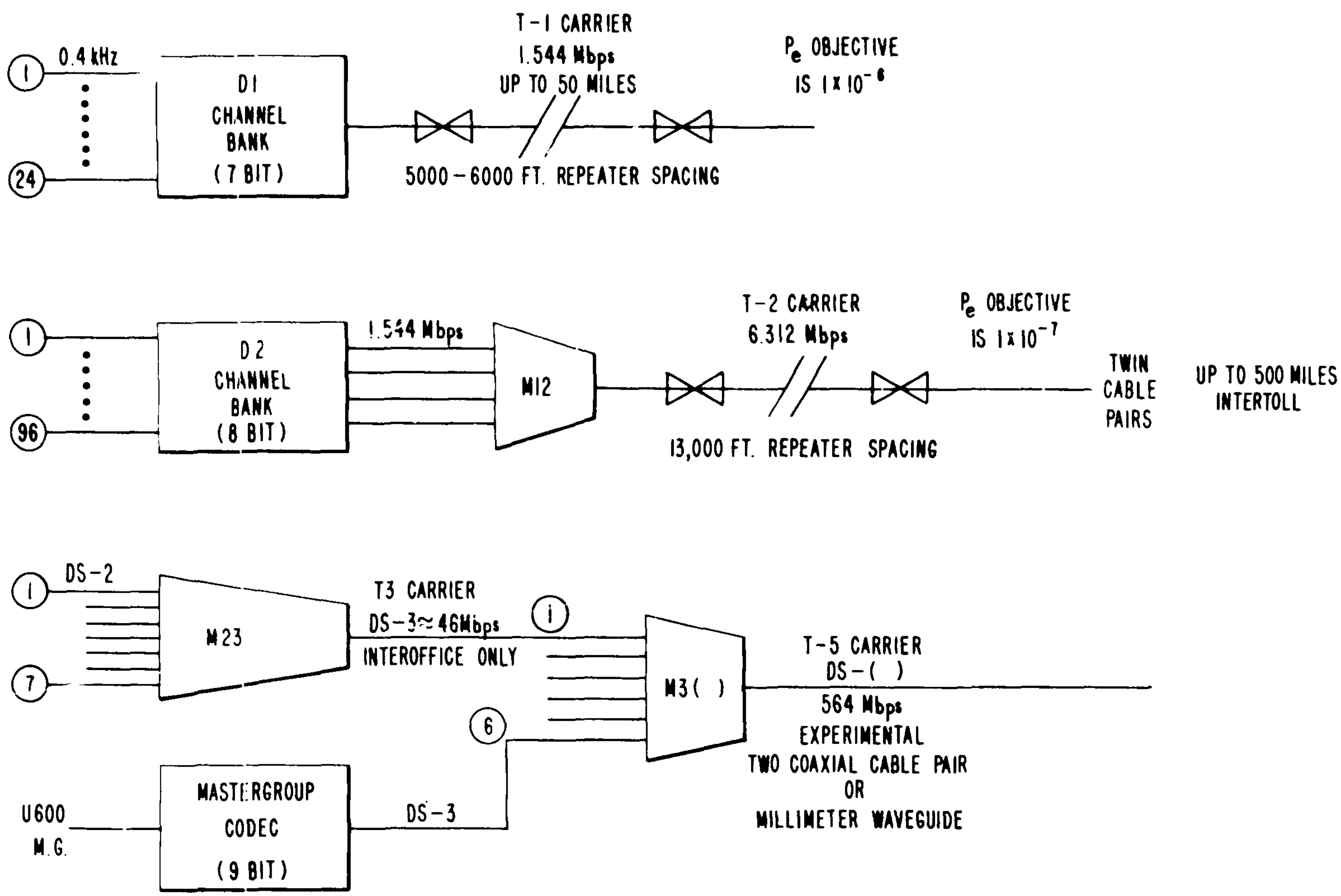

Figure 8. TDM digital hierarchy.

spacing. The microwave radio systems are outlined in table 2.

The digital TDM hierarchy is sketched in figure 8. This network is in early stages of development. Twin cable pairs, coaxial tubes, and microwave radio links are key elements. The T-5 564 MBps link is in the research and development phase.

In the AT&T response to FCC Docket 19311 (11/12/71). AT&T noted that its 1,180,000 channel miles of broad-band microwave in the 2, 4, 6, and 11 GHz bands carry over 60 percent of the interstate voice circuit mileage and nearly all of the network television channel mileage. The 1970 to 1980 interstate telephone message volume excluding WATS is expected to increase from 2.7 billion to 10 billion messages per year. Private line circuits are expected to double. Data transmission volume has grown 50 percent per year, including 35 percent per year during the recent economic slowdown. AT&T estimates that over two-thirds of the <u>interstate</u> circuit mileage required for 1980 has yet to be constructed. In short, over 3,000,000 channel miles must be implemented by 1980. It is not known if CATV network interconnection traffic is included in these estimates.

The interexchange telephone plant is mostly 22 gauge multipair cable. Digital service on these cables is

provided with T1 voice channels. The medium haul (up to 250 miles) telephone plant uses FDM carrier of J, K, O, N1, N2, and N3 type with some L carrier on coaxial tubes. Bandwidth of N2 carrier for example is 104 kHz. The long haul Bell System plant is FDM-FM microwave radio (estimated as $15 billion investment). The Western Union TH3 system, MCI system, and DATRAN system are FDM-FM, as is the COMSAT INTELSAT IV satellite system. This large FDM-FM plant will strongly influence the CATV interconnection.

The Western Union network is shown in figure 9. It is almost entirely designed for data transmission at rates up to 40 Mbps (20 Mbps initially) with TDM-PSK transmissions on microwave radio. The TDM techniques are outlined in table 3 and the Western Union implementation plan is shown in table 4. The network is relatively new.

The specialized common carrier data networks proposed by MCI and DATRAN are described by Martin (1971) and Worley (1972). More recent information concerning DATRAN plans has been given by Karp (1973).

A new common carrier service of importance to CATV regional interconnection is the (MDS) Multipoint Distribution Service. Operations are expected to begin in 1973 in at least seven cities. The system operates in the 2150-2162 MHz band with omnidirectional transmitter antennas

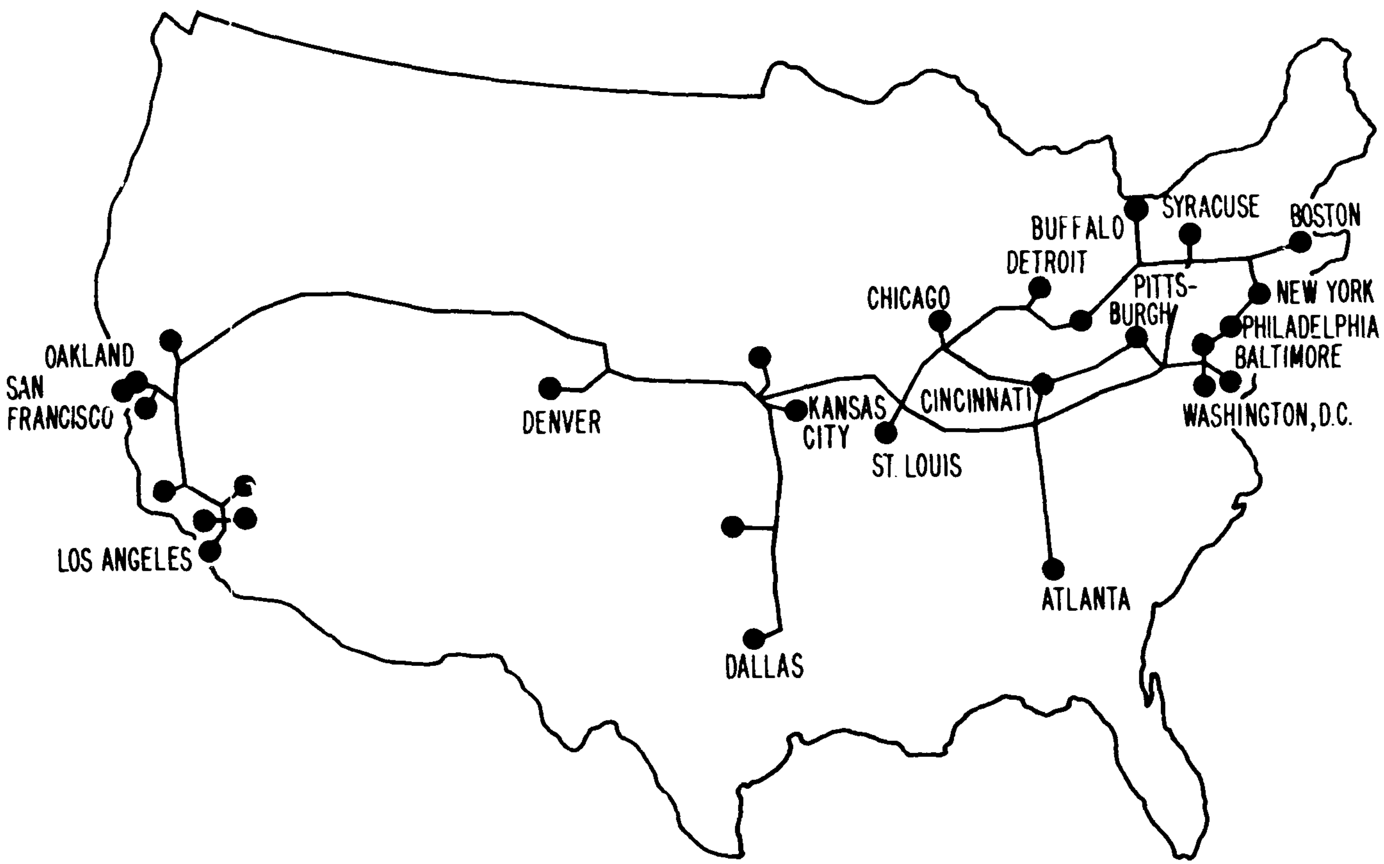

Figure 9. Western Union microwave systems (reprinted with permission from Telecommunications magazine, DeWitt, 1971).

Table 3
Comparison of TDM Techniques

	Efficiency Data Bits/ Line Bits/	Cost/ Channel	Flexi- bility	Primary Uses
Sampling	Low-1/40	Low	Good	Telegraph (0-150) Channels, short haul
Transition Encoding	Medium-1/4	Medium	Good	Telegraph (0-150) Channels long haul 0-1800 bps, 2400/4800 bps
Stuffing	High Almost 1/1	Medium	Good	T1 to 6.3 Mbps 6.3 Mbps to 20 & 40 Mbps 56 kbps to 1.544 Mbps
Character Oriented	High Almost 1/1	Medium to high	Poor	Char. Oriented Telegraph Channels, long haul
Synchronous Network	High Almost 1/1	Medium	Good	2400/4800/9600 bps 56 kbps

Table 4
Chronology of Data Channel Field Trials

Type of Channel	Data Level	Technique	Local Dist. or Long Haul	No. of Chan. in a 64-kb Timeslot	Engineering Field Trial
Teleprinter (0 to 150 baud)	1	Sampling	Local Dist.	7	In Service
2400/4800 bps	2	Transition Encoding	Local Dist.	4	1971
0 to 1800 bps	2	Transition Encoding	Local Dist.	7	1971
Teleprinter (0 to 75 baud)	1	Transition Encoding	Long Haul	144	1972
2400 bps	2	Synchronous Network	Long Haul	24	1972
4800 bps	2	Synchronous Network	Long Haul	12	1972
9600 bps	2	Synchronous Network	Long Haul	6	1972
56 kbps	3	Synchronous Network	Long Haul	1	1972

(100 watts ERP) and directional receiver antennas. A 25 mile range is projected. A down converter is required to translate the VSB-AM picture and subcarrier FM audio signal to a standard television channel. Only one television channel is transmitted.

Auxiliary broadcast services use three frequency bands for studio-to-transmitter, mobile stations, and intercity relays:

Band	Channels	Frequency Range	Bandwidth/Channel
A	7	1990 - 2110 MHz	
A	3	2450 - 2500 MHz	
B	10	6875 - 7125 MHz	25 MHz
D	22	12700 - 13250 MHz	25 MHz

Instructional Television Fixed Stations (ITFS) operate in the 2500 MHz to 2680 MHz band. Point-to-point video transmission on common carrier facilities use A2A cable for local relay, L1 and L2 cable as well as TD-2 and TH microwave radio for intercity video transmissions, and TJ and TL microwave radio for short-haul connections:

Designation	Frequency-Band	2-Way Video Channels
TD-2	3700 - 4200 MHz	6
TH	5925 - 6425 MHz	8
TJ, TL	10700 - 11700 MHz	6

3.3. Comments on Services, Systems and Technology

Interconnection of CATV systems may be viewed as a distribution problem in information exchange. It is informative to consider one-way distribution of audio/video television programs. Wells and Bruce (1972) reported a four-way comparison for public broadcast network distribution of educational television:

a) Shipping video tapes to each television station or CATV system.

b) Terrestrial microwave interconnection with delay at regional centers for time zone differences or individual stations for local station scheduling.

c) Indirect satellite distribution to shared multi-purpose earth stations with terrestrial connections.

d) Direct satellite distribution to a television station studio or a CATV head-end.

A summary is presented in table 5 for the 110 station network. The only cost per station per program hour estimate given by Wells and Bruce (1972) was for shipping video tape. The other estimates were developed with the information given by those authors.

A distinction is made in table 5 between national live broadcast to all 110 stations which record for re-broadcast

Table 5
Cost Estimates for National Public Television
One-Way Distribution

Distribution Method	Average Cost per Station per Program Hr	Added Fixed Investment Per Station	110 Station Total Network Annual Costs (25 hour week)
Videotape Shipping	$43.00 - $73.00	$20,000*	$6-$11 million
Terrestrial Microwave PBS Tariffs	a) $ 86.00	$20,000*	$12.2 million
	b) $121.00	None	$13.7 million
Terrestrial Microwave Commercial Tariffs	b') $190.00	None	$23.7 million
Direct 3 Satellite Broadcast			
a) 2.5 GHz	$90.00	$100,000	$9.3 million
b) 7.4 GHZ	$90.00	$100,000	$9.3 million
c) 12 GHz	$108.00	$100,000	$10.6 million
Indirect Satellite	No estimates given by Wells and Bruce (1972)		

*Cost for two video tape recorders (2 inch with expected 7 year life). Under heavy usage, the cassette type player is expected to have only a 3 - 6 month operating life which diminishes greatly the cost advantage.

(designated a) and national live broadcast to six regional centers which record and re-broadcast to the stations (designated b and c). Actual practice involves a mixture of both. Smaller Public Broadcast stations cannot afford the added fixed cost for recording and thus broadcast without delay.

The direct broadcast by three satellites is proposed for the 2.5 GHz band which is available only to educational or instructional services. Each satellite is postulated to have 24 color television channels with only 6 used the 110 station network. The total system costs are based on the assumption that the satellite system operator would lease 6 channels to the network and lease the remaining channels to other customers.

Further assumptions about the satellites are noteworthy. The television signal received would be CCIR relay grade signal of 56 dB signal-to-noise ratio. Each satellite would have two beams of 1.75 degree beamwidth. The same 12 downlink and 12 uplink carrier frequencies would be used by each satellite. Interference would be avoided through orbit separation and the narrow antenna beamwidths. The satellite system cost estimates are the most speculative since they are not based on any actual system experience. Program origination by any staiton is excluded because the ground

terminals are receive only. For transmission capability at each station, the cost per station per hour would increase about $20. Finally, a 25-hour week was assumed.

The comparison in table 5 is considered relevant to CATV system interconnection because of the satellite terminal high capital investment per station. This would tend to limit the number of CATV systems which would initially participate. The costs are sensitive to the number of hours per week and the number of stations in each region. The important observation is that the costs per subscriber per month for a 10,000 subscriber CATV system for the 25-hour program week are estimated to be on the order of $0.40 to $0.70 for videotape shipping, $1.90 for terrestrial microwave networks, and $0.90 to $1.10 for direct satellite distribution. These appear to be minimum estimates of subscriber cost for only national distribution since no CATV operator administrative or overhead costs are included. In the case of terrestrial microwave and satellite distribution, about $0.55 per month was included for network administration, etc.

If the aforementioned direct satellite broadcast network involved 1000 stations instead of 110, the 25-hour program week distribution cost per subscriber per month could decrease to $0.30 per month, using the results from Wells

and Bruce (1972). Again network administration, scheduling, etc., costs represent a large fraction of the $0.30. These estimates are consistent with the Hughes Domestic Satellite System proposal (Clark, 1972). Hughes has proposed a system to generate programs and distribute them via satellite to CATV operators. Quoted fees would be from $0.25 to $2.00 per month per subscriber. The receive-only earth stations would have 35 foot diameter non-tracking antennas. Ground station costs were estimated by Hughes at $100,000.

Although a more complete study would be desirable, table 6 shows estimates for larger networks with an increased number of program hours per year. The one-way video distribution costs are based on 10,000 subscribers per CATV system. Satellite operation in the 4 GHz and 6 GHz bands is assumed. The question mark indicates unavailable information for this report. The significant observation concerns the relative ordering of the costs. Station costs per subscriber can decrease with an increased number of subscribers, but are strongly influenced by the station antenna costs. Network administration cost projections for increased number of stations would have to be developed for the larger networks.

With some cost estimates established for one-way video distribution, interactive two-way services and costs present

Table 6
National Distribution Cost Estimates for One-way Video to CATV Head-ends

CATV Head-ends (first line) and Yearly Programming Hours (second line)

	110 1300	220 2600	330 3900
Cost Estimates per Station per Hour			
Space Segment	$ 3.60	$ 1.80	$ 1.20
Station Antenna	$15.30	$ 7.65	$ 5.10
Station Delay	$29.50	$23.50?	$20.00?
Network Administration	$56.00	$40.00?	?
Cost Estimates per Subscriber per Month			
Space Segment	$ 0.04	$ 0.02	$ 0.01
Station Antenna	$ 0.15	$ 0.08	$ 0.04
Station Delay	$ 0.30	$ 0.24?	$ 0.20?
Network Administration	$ 0.56	$ 0.40?	?

a contrast. Interactive services require a terminal capable of transmission. While subscriber terminal costs are not an important factor in CATV interconnection, they provide a basis of comparison with the interconnection costs. The subscriber must pay both.

Baer (1971) estimates the costs per subscriber terminal for elementary two-way services between \$150 to \$340 above about \$125 per subscriber per conventional one-way service. Some perspective of these figures can be gained by noting some costs of terminal components. Good quality numeric keyboards (3 by 5 buttons) with encoding logic supplied as OEM equipment cost on the order of \$16 in quantities greater than 10. This would appear to be the simplest response terminal.

Alphanumeric terminals with ASCII coding supplied as OEM equipment in quantities greater than 5000 cost about \$49 each. Again, reasonably good components are involved. Encoded typewriter terminals with modems are available on rental plans in the range of \$100 to over \$300 per month. One device currently available consists of an alphanumeric keyboard, television set attachment, acoustic coupler, and modem. The device operates on the dial telephone switched network with time shared computer terminals. It will display 8 lines of 32 characters each on a conventional

television set. Cost of complete units in quantities greater than 100 is on the order of $1400, with lower prices available in greater quantities.

These figures suggest that Baer's (1971) estimates of $150 to $340 per subscriber would involve only an alphanumeric keyboard type terminal plus related electronics for transmission. Further, the television display signals would have to be generated at the head-end and transmitted at 30 frames/second to the terminal for the duration of the display.

Digressing for the moment from the discussion, a review of these costs and experience with computer time-share terminals suggest that an aggregation of two-way services may probably have to be offered by the CATV operator. These services would have to include much more complex services than those usually included in elementary service lists and most likely will involve interconnection. The reason is that even in mass quantities of production, certain basic costs will not be avoided. Extensive research and development efforst can usually minimize these basic costs but then the unit cost must allow for research and development investment recovery. Hence, the unit cost usually has a minimum. The difficulty with two-way service aggregation is that a multipurpose terminal will probably

have to be designed for the same cost range mentioned by Baer (1971); i.e., $150 to $340 per subscriber.

A second digression concerns a factor usually overlooked in discussions of two-way interactive services involves a learning phase on the part of the individual user. Computer time-share terminal experience in an office environment suggests that the terminals must be simple to operate and simple to learn to operate. These characteristics are often not obtained until the third generation of designs.

Further, the cost of general sales and training efforts in each community must be included. Without pilot programs, these are difficult to estimate. Finally, the service offered via cable must be faster, more convenient, and probably more reliable than the existing methods of obtaining and providing the service. These two digressions suggest that cost estimates for CATV two-way services and particularly interactive two-way services may be underestimated in the literature.

Baer (1971) presented a list of many of the services which are proposed for cable television with two-way capability. These are repeated as tables 7 and 8. Table 7 organizes many of the services into six major categories. All the lists of one-way and two-way services proposed for cable television systems which have been reviewed avoid the

Table 7

Some Proposed Interactive Services for Cable Television[a], From Baer (1971), Reprinted with Permission from RAND Report R-888-MF

Services for Individuals	Services for Business	Services for Government
Interactive instructional programs	Television ratings	Computer data exchange
Fire and burglar alarm monitoring	Utility meter readings	Teleconferencing
Interactive TV games	Control of utility services	Surveillance of public areas
Quiz shows	Opinion polling	Fire detection
Subscription television	Market research surveys	Pollution monitoring
Remote shopping	Computer data exchange	Traffic control
Special interest group conversations	Business transactions	Fingerprint and photograph identification
Electronic mail delivery	Credit checks	Civil defense communications
Electronic delivery of newspapers and periodicals	Signature and photo identification	Area transmitters/receivers for mobile radio
Computer time sharing	Facsimile services	Classroom instructional television
Videophone	Report distribution	Education extension classes
Catalog displays	Industrial security	Televising municipal meetings and hearings
Stock market quotations	Production monitoring	Direct response on local issues
Transportation schedules	Industrial training	Automatic vehicle identification
Reservation services	Teleconferencing	Community relations programming
Ticket sales	Corporate news ticker	Safety programs
Banking services		Various information retrieval services
Inquiries from various directories		Education for the handicapped
Local auction sales and swap shops		Drug and alcohol abuse programs
Direct opinion response on local issues		
Electronic voting		
Subscriber originated programming		
Interactive vocational counseling		
Local ombudsman		
Employment, health care, housing, welfare, and other social service information		
Library reference and other information retrieval services		
Dial-up video and audio libraries		

[a]These services are not all likely to be economically feasible on cable television networks. Some may not even be socially desirable. They have been compiled from various reports, FCC filings, corporate brochures, and advertising materials.

Table 8
Categories of New Cable Communications Services,
From Baer (1971), Reprinted with Permission from RAND Report R-888-MF

Service Category	Downstream Signals	Upstream Signals	Equipment Requirements: Headend Equipment	Equipment Requirements: Subscriber Equipment
I. One-way broadcast services	6 MHz broadcast video channels (FDM)	None, except for local origination which may require one or more video channels from origination points to headend	Additional signal processing and multiplexing equipment; origination equipment	Converter or switch to receive > 12 channels
A. Additional channels TV entertainment programs instructional programs coverage of local events local program origination community bulletin board municipal services information (health, housing, welfare, etc.) local ombudsman				
fm radio foreign radio recorded music	200 KHz radio channels (FDM)			
B. Subscription channels movies entertainment programs instructional programs sports and special events			Signal scrambler or encoder	Unscrambler, decoder or special converter
II. One-way addressed services electronic mail delivery newspaper and periodical delivery selective video	Individually addressed wideband signals (FDM or TDM)	None	Information storage facilities; document scanner; address generator; communications controller	Address decoder and logic unit; video tape recorder, facsimile or other recording unit
III. Narrowband subscriber response services	Broadcast video (FDM), plus individually addressed narrowband polling signals (TDM) of 100 or fewer bits	Narrowband response digital data (TDM of 100 or fewer bits from individuals to headend	Central polling scanner, and communications controller (mini-computer); files, displays and other peripherals	Basic control unit (receiver, digital decoder, control logic, digital encoder and transmitter): buttons or keyboard, channel monitor
A. Interactive television entertainment programs instructional programs opinion polling remote shopping municipal services information				A. identification or authorization key
B. Sensor monitoring audience counting alarm monitoring meter reading cable system maintenance				B. channel sensor fire and intrusion sensors meter encoders amplifier and other component sensors

Table 8 (continued)

Service Category	Downstream Signals	Upstream Signals	Equipment Requirements: Headend Equipment	Equipment Requirements: Subscriber Equipment
C. Control of remote devices alarm sounding utility load control				C. switches and links to controlled devices
D. Subscription television			D. Signal encoder; billing mechanism	D. Decoder or special converter; authorization key
IV. Shared two-way channels	Same as III.	III, plus	III, plus equipment to recognize and queue requests, enable and disable subscriber equipment	III, plus
A. Voice response instructional programs entertainment programs community service information special interest group conversations local ombudsman		A. 3-4 KHz voiceband channel(s) (FDM)		A. Microphone, speaker and associated equipment
B. Video response instructional programs remote medical diagnosis neighborhood program origination		B. 4-6 MHz video channel(s) (FDM)		B. Camera and associated equipment
V. Subscriber initiated services catalog shopping stock quotations ticket and reservation services information from various directories and references computer time sharing computer assisted instruction checkbook balancing and other banking services dial-up video library business credit checks	III, plus individually addressed information (alphanumeric message or picture); bandwidth dependent on type of information, but usually voice-band or greater	III, with narrowband (but sometimes > 100 bit) response	III, plus source data bases (digital data, pictures, etc.) connected to central controller; billing mechanism	III, plus extended keyboard, local storage (buffer or refresh) and output display device (character generator, strip printer, frame freezing device, video tape recorder or facsimile)
VI. Point-to-point services	Individually addressed, variable bandwidths for data, voice and video transmission; primarily FDM with TDM for data	Individually addressed, variable bandwidths for data, voice and video transmission; primarily FDM with TDM for data		
A. Message-switched services message transmission business transactions computer input/output			A. Store-and-forward processor	A. III, plus buffer storage and keyboard printer
B. Point-to-point circuits high speed data exchange facsimile fingerprint or photograph identification teleconferencing closed circuit TV videophone			B. Equipment to set up private or multi-party channels	B. Data, voice, and video terminals as required; special frequency converters and associated logic for channel selection

Table 9

Major Uses for Telecommunications Links (Martin, 1971)
(Reprinted with permission of Prentice-Hall, Inc.)

Service	Switched?	One Way or Two Way	Bandwidth (kilohertz)
Telephone	Yes	2	4
Sound broadcasting (low fidelity)	No	1	5
Sound broadcasting (high fidelity, stereophonic	No	1	40
Music library	Possibly	1	40
Television broadcasting (color)	No	1	4600
Large wall screen television	No	1	20,000 to 50,000
Closed circuit television intercommunications	Possibly	1 or 2	4600
Movie selection in the home	Possibly	1	4 to 100
Stored television	Possibly	1	4 to 1000
Still pictures on television screen	Possibly	1 or 2	4 to 100
Facsimile	Possibly	1 or 2	4 to 1000
Teaching devices	Yes or No	2	Any, commonly 4
Advertising	Yes or No	1	Any,
Shopping	Yes	1 or 2	4 to 4600
Mobile communications	Yes or No	2	25
Voting by the public	Yes or No	2	<1
Alarms (fire, burglar, System Failure, etc.)	Yes or No	1	<1
Emergency communications	Yes	1 or 2	4
Telegraphy	Yes or No	2	<1
Batch data transmission	Yes or No	2	<1 to 1000
Acess to time-shared computers	Yes or No	2	<1 to 4
Real-time systems, such as airlines reservations	Yes or No	2	Commonly 4
Fast alphanumeric man-computer "conversation"	Yes or No	2	4
Man-computer conversation with graphics	Yes or No	2	4 to 1000
Man-computer conversation with voice answerback	Yes or No	2	4
Banking and credit systems	Yes or No	2	<1
Data collection systems	Yes or No	1 or 2	<1
Intercommunication between computers	Yes or No	2	Any
Automatic meter reading (utilities)	Yes	1	<1
Vehicle traffic control	No	2	<1
(or perhaps alternatively:)	No	1	1000 to 5000

question of why a cable system must be constructed to provide such services. An exception is given in table 9 which was abstracted from Martin (1971).

A second question of importance concerns whether the CATV operator would require any regional or national interconnection to provide the service. Any comprehensive evaluation of even a single service would require an extensive system design and analysis. This was not done as part of the preparation of this report. Hence, table 10 represents another speculative list in this sense.

Through eliminating duplications table 7 was reduced to the 55 entries in table 10. Of these, only 14 definitely would need a CATV system with five additional services in question. The other services could potentially be provided by other existing systems. One could argue that a rational trade-off analysis between CATV systems and an alternate system implementation be explored independent of current regulatory policy. On the other hand, the provision of many services on a CATV system with a single terminal appropriately designed could be explored. Finally, it is important to note that CATV may be necessary with no alternatives when an aggregation of multiple services is considered. This seems to be an important analysis which has not been published in the literature.

Table 10

Review of Proposed Interactive Services for Cable Television

Services For Individuals	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Interactive instructional programs:			
alphanumeric display	Telephone network	Yes	Local or regional origination may be desired.
full video	None*	Yes	
Interactive TV games:			
alphanumeric display	Telephone network	Yes	
full video	None	Yes	
Quiz shows audio return	Telephone network	?	Audio/video return feasibility would be questionable until some system designs are well developed.
audio/video return	?	?	
Subscription television	VHF or UHF Broadcast television	Yes	This has been delayed since first proposals during the early 1950's.

*None in this column indicates that a CATV system or one with similar bandwidths would be needed but that point-to-point switching would not be needed.

Table 10 (continued)

Services For Individuals	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Remote shopping	Telephone system in conjunction with UHF television broadcast	Possible Regional	This would seem to require major changes in merchandising systems with extensive software development.
Special interest group conversations	Telephone network	No	
Electronic mail delivery	Telephone network	Yes	See facsimile discussion in text and Baer (1971).
Electronic delivery of newspapers and periodicals	Data networks and telephone system	Yes	Local wiring to be installed for AT&T Picturephone* service would have capacity.
Computer time-sharing	Data networks and telephone system	Yes	Numerous networks already in existence.

*Registered AT&T Trademark

Table 10 (continued)

Services For Individuals	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Videophone	Telephone system	Yes	National videophone service poses a capacity growth problem for telephone industry as well as CATV interconnection.
Catalog displays	Telephone system in conjunction with VHF or UHF broadcast	Yes	
Stock market quotations	Telephone system	Yes	
Transportation schedules, Reservation services Ticket sales	Telephone system	Yes	
Banking services	Data network and telephone system	Yes	Networks in existence - would require extensive changes in service delivery (see text).

Table 10 (continued)

Services For Individuals	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Inquiries from various directories	Telephone system	Yes	
Local auction sales and swap shops	None	No	Feasibility with CATV needs to be established.
Direct opinion response on local issues	Telephone system	No	
Electronic voting	Telephone system	Yes	
Subscriber originated programming	None	?	Feasibility with CATV needs to be established.
Interactive vocational counseling	?	?	Feasibility of counseling through telecommunications not demonstrated.
Local ombudsman	?	?	Service must be defined better.

Table 10 (continued)

Services For Individuals	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Employment, health care, housing, welfare, and other social service information	Telephone system	Yes	Interactive CRT terminal desirable.
Library reference	Telephone system	Yes	
Audio libraries on dial-up basis	Telephone system and dedicated lines or AM, FM broadcast radio	Yes	Queueing versus system capacity problems not worked out.
Video libraries on dial-up basis	None	Yes	Queueing versus system capacity problems not worked out - serious feasibility question.
Services For Business			
Television ratings, utility meter readings, control of utility services	Telephone system	Yes	

Table 10 (continued)

Services For Business	Feasible Alternate Telecommunication System	Interconnection Needed or Beneficial	Remarks
Opinion polling	None	?	Depends strongly whether or not film or video is used.
Market research surveys	None	?	If not, telephone may be adequate.
Computer data exchange	Data networks and telephone system	Yes	Networks in development and in existence.
Business transactions	Data networks	Yes	Must be carefully defined.
Credit checks	Telephone or data network	Yes	
Signature and photo idenfification	Telephone Picturephone* network	Yes	Photo idenfication in both cases may pose resolution problems.

*AT&T Registered Trademark

Table 10 (continued)

Services For Business	Feasible Alternate Telecommunication System	Interconnection Needed or Beneficial	Remarks
Facsimile services	Telephone and data network	Yes	See text for facsimile discussion.
Report distributio	Telephone and data network	Yes	
Industrial security	Closed circuit TV with CATV	?	
Production monitoring	Closed circuit TV	?	
Industrial training	None	?	
Teleconferencing	?	Yes	Feasibility is a serious question even if capacity were available. Capacity and queueing are also problems.
Corporate news ticker	Telephone system	Yes	Non-interactive CRT terminal.

Table 10 (continued)

Services For Government	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Surveillance of public areas	None	?	
Fire detection	?	?	Detection systems data rate unknown.
Pollution monitoring	Telephone and data network	National Weather Service networks now exchange data	
Traffic control	None	No	
Fingerprint and photographic identification	Data networks	Yes	Currently under development or in use by Law Enforcement agencies or Defense agencies.
Civil Defense communications	Broadcast Radio and television	Yes	Major networks now in existence.
Area transmitters/ receivers for mobile radio	Telephone system	Yes	

Table 10 (continued)

Services For Government	Feasible Alternate Telecommunications System	Interconnection Needed or Beneficial	Remarks
Classroom instruction television	None	Yes	
Education extension classes	None	Yes	
Television municipal meetings and hearings	UHF television broadcast	No	
Automatic vehicle identification	Telephone system	No	
Community relations and safety programs	None	Yes	

Table 10 resulted in a need for or benefit from interconnection for 33 services, with 11 additional services questionable. This is independent of the type of system used for interaction and/or distribution of the service. Since some of these services are already being implemented in the business and government sectors, the impetus for interconnection capacity seems to exist.

For comparison, Callais and Durfee (1971) list the following services initially implemented for the Hughes Aircraft Company (and Theta-Com) Subscriber Response System (SRS) two-way system:

Remote Channel Selection	Opinion Polling
Premium TV (6 channels)	*Emergency Alarm
Restricted TV (2 channels)	*Meter Reading
Channel Polling	*Accessory Power Control

The three services marked by an asterisk were interface connections for auxiliary devices which were not part of the subscriber response console unit. In addition, a two-way message capability service is possible which suggested reservation services, some home shopping services, etc. The SRS console consisted of a voltage-controlled varactor tuner, strip paper printer, four function keys, and a 3 by 4 numeric keyboard with associated electronics.

As a final comment, it must be remarked that the ongoing and planned experimental systems could change specific results in table 10. However, the number of experiments is not large enough to have an immediate impact.

Numerous authors introduce a hard copy terminal as an element of a business or home terminal served by a CATV system. Systems and equipment for transmission of graphic and textual printed material by telephone and radio have been in operation in numerous applications for some time. Facsimile involves conversion of the printed material into electrical signals (scanner), modulation (if analog), or analog to digital conversion, possible encoding and then modulation (if digital), transmission, demodulation, and, finally, conversion to printed material (recorder) by some printing or photographic process.

Manufacturers are numerous as witnessed by the list of 68 different models offered by 15 companies, Auerbach (1971), with two additional companies listed in a recent survey by Stafford (1971). With vertical resolutions between 83 and 190 lines per inch, the monthly lease costs of 25 different facsimile terminal units are shown in figure 10 as a function of transmission time per page. These costs are based upon a single terminal which has both a scanner and recorder. The costs and times are approximate

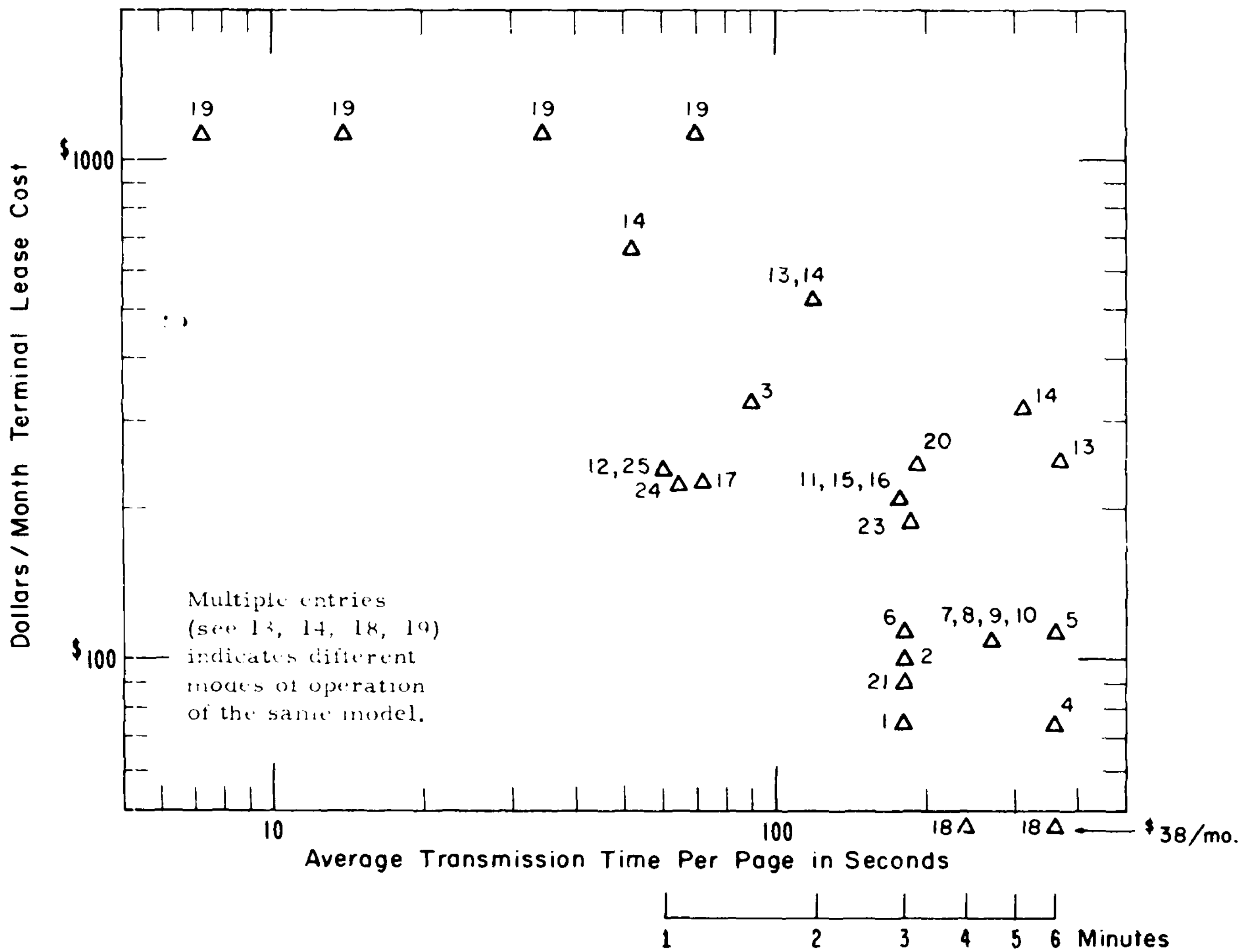

Figure 10. Facsimile summary.

(Stafford, 1971). The transmission time, based on averages for nominal 8 1/2 x 11 inch pages, is that provided by the manufacturer for the corresponding resolution.

Although a number of other available flatbed facsimile equipments as well as drum scanning equipments may be added to figure 10, the overall trends would not change appreciably. The lease expensive equipment to lease has average transmission times per page of 6 minutes.

A cluster of models in figure 10 is available in the $75 to $140 per month range with transmission times from 1.1 to 6 minutes per page. Another cluster appears between $200 and $600 per month with transmission times in the 1 to 5 minutes range. The fastest transmission speed models operate as low as seven seconds per page at a lease cost of $1200 per month. Faster models are available, but not on a lease basis.

Another aspect of facsimile service is shown in figure 11. An example was prepared for six models for a transmission distance of 1500 miles. The cost in dollars per month is shown versus the monthly utilization in pages transmitted per month. Operator labor costs are based on $7,000 per year salary with a 2.3 overhead factor and unattended reception so that only one operation is needed.

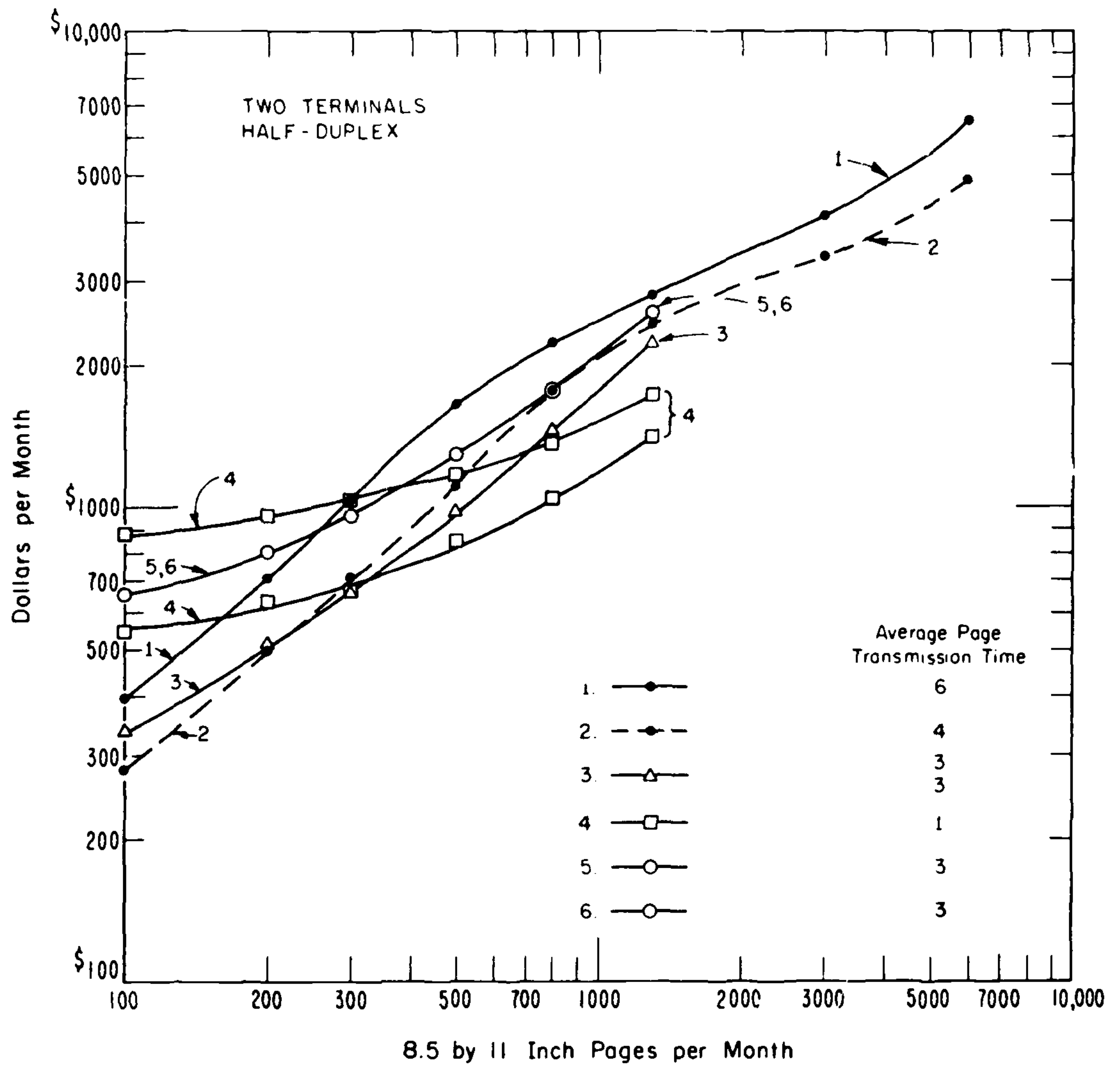

Figure 11. Facsimile operating costs with commercial day telephone rates and operator labor.

Facsimile development as a means of distributing documents has been inhibited by the cost of the terminals for high speed units and the leased or dial transmission line costs of the common carriers. It would appear that a CATV system can overcome the bandwidth limitation in a local area although point-to-point service will increase the cost. The terminal costs will be the same, though, until the market develops to lower costs through sales volume. It remains to be seen how interstate transmission through CATV system interconnection can be provided at rates substantially below present common carrier tariffs.

4. THE NEED FOR INTERCONNECTION

Does a need for CATV interconnection exist? This question is examined in this section. A number of examples are cited to show the relationship between a particular service and the extent of interconnection needed. Two primary observations are made. They suggest that a need for interconnection exists if the projected services for CATV implementation are to be developed.

First, some services may need very little interconnection when fully implemented on a large scale basis in the future. However, substantial interconnection

may be required during the growth transition from the present to future condition of full implementation because initial markets may not be large enough in any one area to justify the initial capital investment. Remote shopping is cited as an example.

Second, a number of proposed services require computer software development or video programing. The costs involved suggest the need for interconnection in order to reduce the cost per subscriber.

Finally a potential method of experimenting with proposed services is suggested. Existing computer-communication networks are suggested for pilot programs to define services and outline the development efforts necessary to implement these services in CATV systems.

In previous discussions it was estimated that 33 proposed services might have a potential need for CATV system interconnection or might benefit from interconnection on a regional or national basis. These needs or benefits are sensitive to the particular services considered and the system implementations as well as the number of subscribers requesting a service at any one time. The potential exists for some services to need extensive computer facilities and cable television channels within a local area possibly as small as 5000 subscribers. The need for interconnection for

these services may be small. CATV systems could grow in local areas with a large percentage of the signals originated and received completely in the local area.

This might result, for example, if local transportation by automobile were to be partially replaced by the television shopping and work-at-home television services. If shopping were to be performed on an interactive basis, medium to large computers would be needed in each local area. While technically feasible in a superficial sense*, such services require a change in our shopping habits as well as substantial system design effort to avoid potential queueing problems (section 5.4). The number of cable television channels needed may be large.

If remote shopping from the home is to be developed with CATV systems, the possibility exists that pilot systems may be implemented using regional networks to interconnect a number of existing CATV systems. The retail merchandise organizations would then be able to obtain a large subscriber base to investigate market feasibility. Further investment in required central facilities could be made as demand grows by sub-dividing the networks. Finally,

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*Until a prototype system is constructed and operated, a statement of technical feasibility must be regarded as suspect.

existing common carrier network facilities could be leased initially to minimize capital investment.

On the other hand, the interactive educational services proposed give examples of services which require program development and more immediate interconnection. They can be used as a basis for cost estimation. Estimates range between $3,000 to $10,000 per hour or more for two-way learning programs. Video training tapes for corporation training are usually estimated at $15,000 for 30 minutes color with graphics and voiceover. Production costs generally run between $600 to $1,000 per minute. At standard commercial television rates, a one-half hour program development usually costs $90,000. The cost of feature films for CATV have been estimated to range from $200,000 per hour to total costs of $800,000 each.

These estimates exclude all administrative distribution and CATV owner charges. They vary on a subscriber basis as basic costs shown in table 11. The lowest cost is the $3,000 per hour two-way instructional program, and the higher cost is the $800,000 feature film. With some exceptions the program materials would be used by a subscriber only once. Exceptions would include activities such as TV games and instructional refresher material. Feature films can be rerun at later dates.

Table 11
Cost of Program Development

	Number of Subscribers		
	2000	10,000	8,000,000
Cost per Subscriber	$1.50 to $400.00	$0.30 to $80.00	$0.0004 to $0.10

Subscriber cost estimates which have been market tested and found acceptable are not available with the possible exception of feature films. CATV offered feature films will probably be priced competitively with local theaters ($2.00-3.00 per subscriber). The previously discussed distribution costs, administrative costs, and profits must be added to table 11. The number of subscribers needed to bring subscriber fees into a reasonable range appears to be too large for most CATV systems to originate a significant amount of this type of programing. MSO companies may approach the necessary cost-effective scale of number of subscribers. More likely, national or regional suppliers will develop to serve numerous CATV systems. Hence this type of programing may need regional and national interconnection to achieve reasonable subscriber fees.

Another need for interconnection is related to computer time-share capacity and computer-communications networks for the time-share, interactive services (IEEE Proceedings, 1972).

Interactive services in computer time-share systems tend to be burst events in time. The events are generally characterized with a long delay between request events, slow data rates during transmission, and very short expected delays for the computer to respond. With the video display, the expected data rates may have to increase substantially. While this is feasible with the wide bandwidth cable on a local basis, the impact on the computer requirements is not minor. Computer time-share Input/Output is currently not available on a widespread basis even at 1200 baud. Further, systems have not been operated with as many as 10,000 time-share terminals.

In order to obtain larger computer capacity, a computer communications network can be used. Although this field is relatively new, a number of such networks are currently operating in the United States. Interconnection raises a number of questions to be resolved concerning software development costs and the number of terminals which can be served simultaneously.

Software development costs must be distributed among a number of CATV systems to minimize the cost per subscriber. One means of developing interactive time-share computer services without a substantial investment in computer hardware would involve the use of an existing computer-

communications network. Since a question of feasibility is involved, a demonstration program could be developed using the ARPA computer-communications network described by Roberts and Wessler (1970) and Ornstein et al. (1972). The network is outlined in figure 12.

One of the anticipated problems in CATV system growth is the potential absence of a variety of two-way, interactive programs to offer customers with two-way capability. Aside from conventional uses of computers for storage and access to motion picture and video frames, use of the digital computer has a potential for generating original video programs through computer animated graphics. No studios are needed. Almost all universities have digital computer facilities available which could be used in this way. Further, many government labs and corporations have similar digital computer facilities as do time-sharing computer companies.

This is an existing resource which could be used for original program generation by people throughout the country. Access to and distribution of these programs (both one-way and two-way types) would require a computer-communications network similar to the ARPA net. In fact, a hierarchy of nets may be needed eventually.

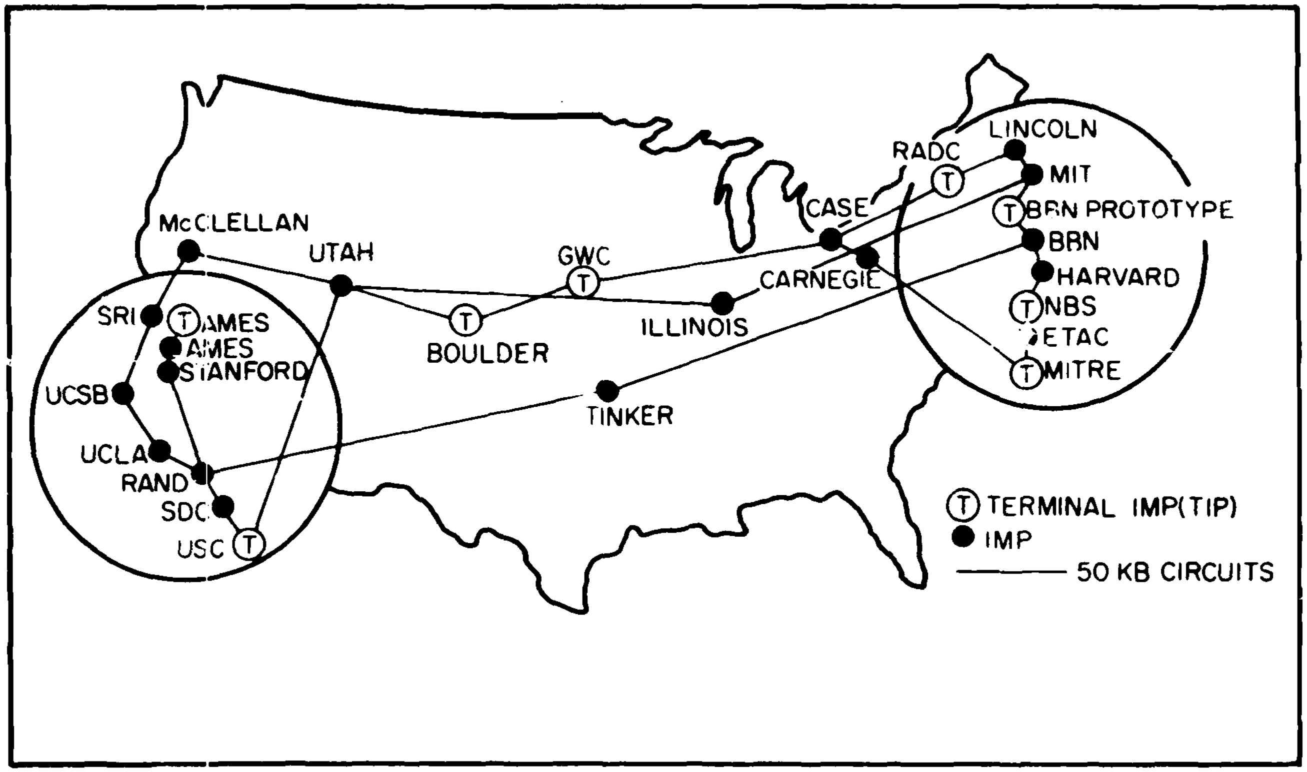

Figure 12. ARPA network, geographic map, March 1972, after Ornstein, et al. (1972).

A second anticipated problem concerns the development of interactive languages which are in the vernacular rather than languages such as FORTRAN, BASIC, etc. If two-way interactive services are to be successful in CATV or Broadband Communications services, it would be beneficial if the languages and protocol used are simplified relative to those available today. Again, feasibility could be demonstrated by use of the ARPA network or similar commercial computer time-share networks. The impact of these techniques on network protocol, computer software, and terminal design may be significant.

The top 100 television markets may eventually each need a major computer system in the local CATV network in addition to interconnection in a computer communications network. Park (1972) estimated that one-way entertainment television distribution including distant signals would achieve 20 to 35 percent penetration near the center and 30 to 60 percent penetration near the edge of the 35 mile zone in the top 100 markets. If these estimates are reasonably good, one-way television distribution provides a base for the introduction of two-way services.

5. SYSTEMS

Consideration of systems for CATV interconnection involves a substantial number of topics. This section addresses three of the more important of these topics. First, the major transmission systems which might be used are considered. These involve communication satellites and line-of-sight terrestrial microwave circuits. Second, the modulation is considered in terms of analog modulation versus digital encoding and modulation. Finally, the queueing aspects of services, number of subscribers, and waiting times for service are discussed.

Satellite links and terrestrial microwave circuits actually form the basis for a system but do not raise the substantial questions concerning the system configuration, protocol timing, and performance requirements. As an example, interconnection networks in star, loop, or tree configurations could be considered. The survey has not uncovered any major efforts involving system designs configured other than common carrier systems reported in section 2. Design efforts needed to make comparisons were beyond the scope of this survey.

5.1. Satellite Transmission

Interconnection of CATV systems on a regional and/or national basis with communication satellites cannot be discussed in terms of any existing satellite systems. All the proposed systems which would interact with most CATV systems have yet to be launched. Although the INTELSAT series and the ANIK I (Canadian Domestic Satellite) are operational, they do not provide primary coverage of the United States. The INTELSAT IV and ANIK technical characteristics are important, though, because the same technology will be used in the U.S. Domestic Satellites.

Within the next five years the NASA ATS-F satellite and the U.S. Domestic Satellites will be launched. These satellites will provide as yet undefined service to the CATV industry. On an experimental basis the Canadian Technology Satellite to be launched by NASA is of interest. Finally the technology under study for INTELSAT V will have implications relevant to the next generation of communication satellites because of the probable use of digital transmission techniques and modulation.

Power, antenna gain, and frequency bandwidth influence the satellite transmission of television signals. Narrow bandwidths (around 5 MHz) require use of SSB-AM or digital modulation (with extensive data compression) and the

communication range is largely controlled by the power and antenna gain. The synchronous satellite ranges are on the order of 22,000 miles one-way. Free-space propagation losses increase from 177 dB at 470 MHz to 200 dB at 6 GHz and 204 dB at 10 GHz. If high index FM is used, a lower carrier-to-noise ratio is possible because of the FM demodulator processing gain in the receiver. This permits use of less power or antenna gain. The wide bandwidth (25-30 MHz for a 5 MHz television signal) is traded for smaller power or antenna gains*.

Direct satellite to home broadcast is always of interest. With current satellite power capabilities at 800 MHz, a seven foot parabolic antenna would be needed to obtain a 32 dB signal-to-noise ratio at the input to a standard home television receiver. The picture quality associated with this signal-to-noise ratio was considered only passable by 90 percent of viewers in the TASO study. Basically about 6,000 watts satellite power per channel would be needed for SSB-AM direct reception with a simple antenna.

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*Smaller antennas usually result in larger sidelobes and may contribute to an increase in interference from other synchronous orbit satellites.

The ATS-F satellite to be launched in 1974 will have an 860 MHz direct broadcast experiment using 40 MHz FM bandwidth, 80 watts transmitter power, and a 30 foot parabolic antenna on the satellite. The receive only ground station will use a 10 foot parabolic antenna and a low noise FM to AM converter television set front-end (Rao et al., 1972) to provide a CCIR-B grade signal. This signal quality is not sufficiently high to permit CATV head-end reception and system cable distribution. This type of system design has been studied extensively by C.C.I.R. (1972).

For the immediate future the conclusion is suggested that direct satellite broadcast of television signals to homes does not appear economically feasible with present technology. The costs would be on the order of $1000 per home at the present time. To change this situation, higher power communication satellites are needed for those frequency allocations which don't have power flux density limitations because of potential interference to terrestrial microwave systems. The 11.7-12.2 GHz band does not have a power flux density limitation. Newman, et al. (1971) and Andrus (1971) have studied the broadcast requirements in this band and have shown that no problems of technical feasibility exist.

Information on the frequency bands that are allocated in Region 2 (including U.S.A.) for FIXED SATELLITE (Earth-to-space), FIXED SATELLITE (Space-to-earth), and BROADCASTING-SATELLITE services is summarized in tables 12, 13, and 14, respectively (ITU, 1968, 1971). The number of earth and satellite services sharing each band are provided along with the number of allocation notes included in ITU (1968). These numbers provide an indication of possible frequency sharing problems. Only two FIXED SATELLITE allocation bands provide for within-the-band, earth-to-space, and space-to-earth transmissions, i.e., 220-230 GHz and 265-275 GHz. With the frequency sharing requirements in the common carrier terrestrial microwave bands, the satellite radiated power flux density is limited. No sharing with earth services is presently allocated in bands above 19 GHz.

Marsten (1972) describes the NASA ATS-F satellite Educational Television Broadcast one year experiment to be conducted by the Rocky Mountain Federation of States (Denver, Colo.) under HEW and Corporation for Public Broadcast sponsorship. ATS-F is designed for a two year life and has twelve other experiments on the satellite. The ETV experiment downlink broadcast will be in the 2500 MHz to 2690 MHz band with 15 watts transmitter power. The 30 foot ATS-F parabolic antenna with multiple feeds will provide two

Table 12
Fixed Satellite (Earth-to-space) Allocations

Frequency Band (GHz)		Regions Excluded	Number of Region 2 Sharing Services Earth	Satellite	Allocation Notes	Radio Regulation Page Number RR5-
2.655	2.690	1	2	1	7	82
4.400	4.700		1	0	0	86
5.725	5.850	2,3	N/A	N/A	N/A	86
5.850	5.925		N/A	N/A	N/A	92
5.925	6.425		2	0	0	92
7.900	7.975		2	0	0	95
7.975	8.025		0	0	1	95
8.025	8.175		2	1	0	96
8.175	8.215		2	2	0	96
8.215	8.400		2	1	0	96
10.95	11.20	2,3	N/A	N/A	N/A	103
12.50	12.75	3	2	0	0	104
14.00	14.30		1	0	1	104
14.30	14.40		0	1	1	104
14.40	14.50		2	0	2	104
27.50	29.50		2	0	0	110
29.50	31.00		0	0	1	110
50	51		0	0	0	113
92	95		0	0	0	115
140	142		0	0	0	115
220	230		0	1	0	116
265	275		0	1	0	116

Table 13
Fixed Satellite (Space-to-earth) Allocations

Frequency Band (GHz)		Regions Excluded	Number of Region 2 Sharing Earth	Services Satellite	Allocation Notes	Radio Regulation Page Number RR5-
2.500	2.535	1	2	1	5	81
3.400	3.500		2	0	1	86
3.500	3.700		3	0	0	86
3.700	4.200		2	0	1	86
7.250	7.300		0	0	2	92
7.300	7.450		2	0	1	93
7.450	7.550		2	1	1	93
7.550	7.750		2	0	1	93
10.95	11.20		2	0	0	103
11.45	11.70		2	0	0	103
11.70	12.20	1, 3	3	1	2	103
12.50	12.75	2	N/A	N/A	N/A	104
17.70	19.70		2	0	0	108
19.70	21.20		0	0	1	108
40	41		0	0	0	113
102	105		0	0	0	115
150	152		0	0	0	116
220	230		0	2	0	116
265	275		0	1	0	116

Table 14
Broadcast Satellite Allocations

Frequency Band (GHz)		Regions Excluded	Number of Region 2 Sharing Services Earth	Satellite	Allocation Notes	Radio Regulation Page Number RR5-
2.500	2.535		2	1	5	81
2.535	2.550		2	0	4	81
2.550	2.655		2	0	5	81
2.655	2.690		2	1	7	82
11.70	12.20		3	1	2	103
22.50	23.00	1,2	N/A	N/A	N/A	108
41	43		0	0	0	113
84	86		0	0	0	114

beams with dimensions of 360 miles in the east-west direction and 500 miles in the north-south direction over the Rocky Mountain region. Frequency modulation with a 25-30 MHz bandwidth will be used for one video signal and at least four multiplexed audio subcarriers. There are no satellite radiated power flux density limitations in the 2500-2690 GHz band.

The purpose of the experiment is to determine the feasibility of direct satellite educational television multi-lingual broadcasts to remote regions for home, school, and community center television reception; CATV head-end reception; and educational television broadcast station reception. The uplink transmission to the satellite will be at 6 GHz. The ground receive terminal will consist of an antenna (7-10 foot simple parabolic dish), low-noise-figure receiver (2 dB to 7 dB noise figure depending on cost), down converter, and FM to AM converter. An output picture signal-to-noise ratio of 47 dB, CCIR weighted, is the objective. The current cost projections for the single channel receiver package is $800-$1000 each in quantities of 500. For comparison, the uplink transmission terminal cost would be approximately $150,000 to $200,000. This is an important experiment for CATV system interconnection. Unfortunately, if the experiment is successful, the only

services which could be transmitted in that frequency band are educational services.

Comsat's INTELSAT IV satellites are in orbit and operational. The INTELSAT IV satellite has 12 fully redundant repeater-transponders with a usable bandwidth of 432 MHz. The satellite receive frequency band is 5932 MHz to 6418 MHz and the transmit band is 3707 MHz to 4193 MHz. The TWT output powers are about 7 watts. A global (17 degree) antenna beam and a spot (4.5 degree) antenna beam are used. Total communications capacity is 3000 to 9000 two-way telephone calls or 12 simultaneous color TV channels.

The Canadian Domestic Satellite is now in synchronous orbit with 12 transponders, each capable of 960 one-way voice telephone channels or 1 color TV broadcast. Each independent channel has a bandwidth of 36 MHz and at least 33 dBW effective isotropic radiated power throughout Canada. Spacecraft lifetime is estimated at 7 years. The output TWT amplifier of each channel operates as a saturated final amplifier to provide 5 watts output power. The repeater schematic is shown in figure 13. It is representative of most proposals for the U.S. Domestic Satellites.

Two channels on ANIK I are available for lease. All 12 channels on ANIK 2 will also be available to lease after

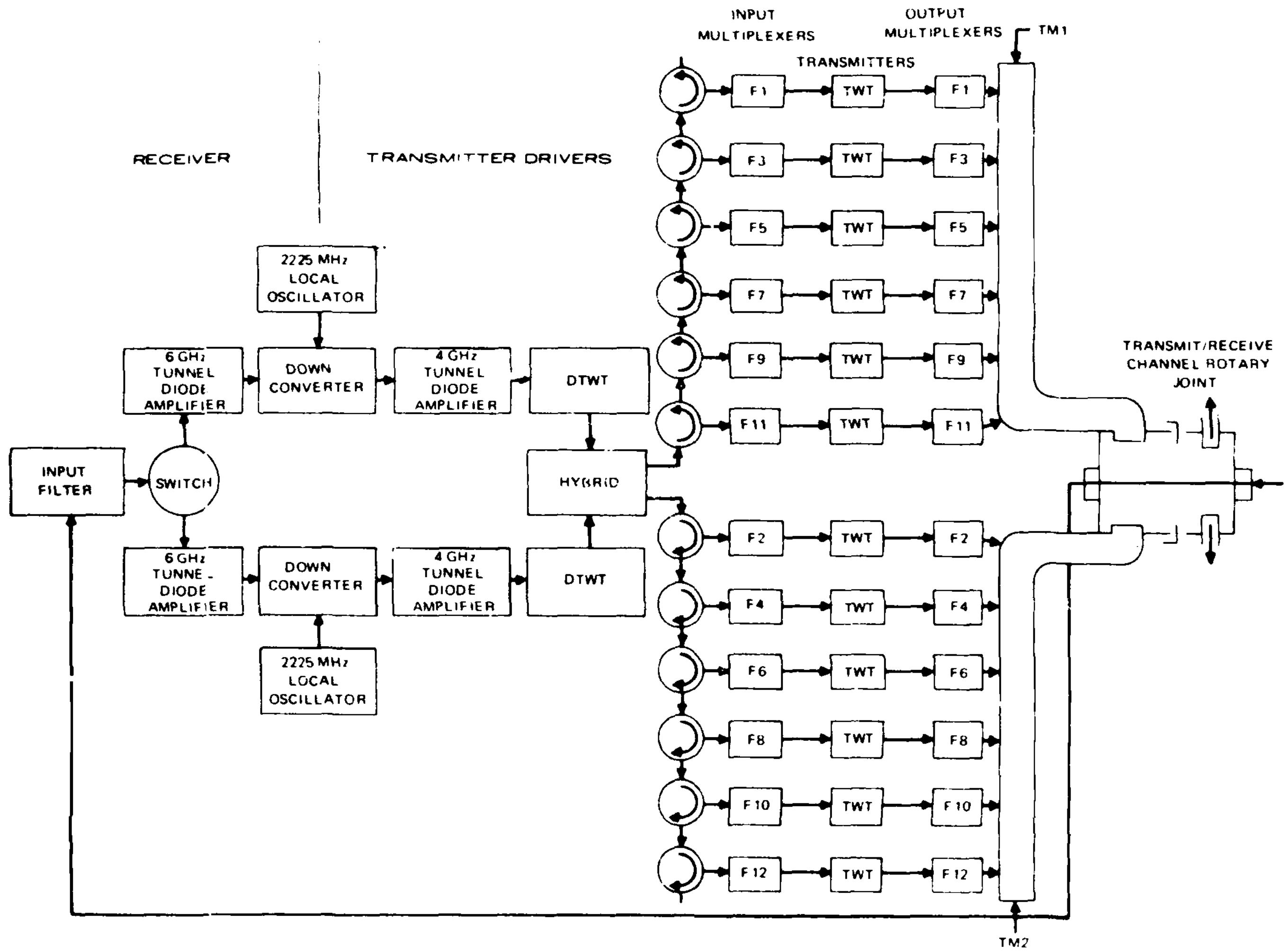

Figure 13. Canadian domestic satellite communications repeater schematic (reprinted with permission, Harrison, 1971).

launch in April of 1973. These channels are available for lease to United States Corporations on a temporary basis. RCA has made an agreement to use one channel of ANIK 2 starting in June 1973. The American Satellite Corporation (AMSAT), a joint venture between Fairchild Industries and Western Union International, has agreed to lease two channels for one year. Other leases are expected in the near future by U.S. corporations which have proposed a U.S. Domestic Satellite System. Lease costs per channel are estimated at $2.5 million per year. These costs are consistent with those used in section 3. These satellites represent an opportunity to develop a pilot CATV television experiment within the limitations of the satellite antenna coverage patterns.

Proposals for the U.S. Domestic Satellite Systems are somewhat difficult to summarize accurately since they are in a state of change. Initial proposals totaled about 600 transponders in orbit with each transponder capable of one color TV broadcast or about 900 to 1000 FDM/FM voice channels or a 34 Mbps data stream. One notes from the digital versus analog discussion in section 5.3 that over five monochromatic digital television signals might be multiplexed in the 34 Mbps data stream in the future.

Table 15 gives a general summary of the proposed system characteristics. Table 16 summarizes individual system parameters including total system investment cost estimates and per channel space segment cost estimates.

Use of satellite circuits in television and data transmission for CATV applications was discussed in section 3, including cost estimates. At the time of this report, eight applications* to build domestic satellite systems are pending before the FCC (Wall Street Journal, 1972). A current restriction limits A.T.&T. to use satellites for regular and wide-area or WATS telephone service and to provide private-line communications to the federal government. These restrictions will terminate in three years after A.T.&T. offers satellite service. It appears from table 16 that the eight applications involve on the order of 280 transponders. Each transponder is designed to relay one color television signal using high index FM when television signals are to be relayed.

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*A.T.&T. and Comsat; Comsat and Lockheed Aircraft Corp. and MCI Communications Corp.; Western Union Telegraph Co.; Western Telecommunications, Inc.; Fairchild Industries, Inc.; RCA Global Communications, Inc.; RCA Alaska Communications, Inc.; Hughes Aircraft Co.; and GTE Service Corp. (see also Barmat, 1971). Fairchild Industries and Western Union International, Inc. have formed the American Satellite Corp. as a joint venture and recently announced purchase of three 12-transponder communication satellites (Wall Street Journal, 1973).

Table 15
General Summary: U.S. Domestic Satellite System Characteristics

Transmitter Power	- 12 watts to 3kW
Transmitter Bandwidth	- 34 to 40 GHz
Antenna Size	- 32 to 105 feet
Antenna Gain	- 4 GHz 54.3 to 59.4 dB 6 GHz 57.8 to 62.9 dB
Antenna Beamwidth	- 4 GHz 0.18 to 0.32 degrees 6 GHz 0.12 to 0.21 degrees
Noise Temperature	- 60 to 150 degrees K
G/T	- 35.3 to 41.2 dB
Azimuth of Radiation	- 102 to 265 degrees
E.I.R.P. Main Beam	- 73 to 92.5 dBW
E.I.R.P. Horizontal Plane	- 3 to 25.8 dBW/4 kHz

Table 16
General System and Earth Station Characteristics[a]

Total System Investment $ x 10^6	82.6	248.4	197.7	229.4	210.8		67.7	241.4	94.6	
Per Channel $ x 10^6 Space Segment Investment	Hughes 1.78	Comsat 2.32	RCA 2.02	MCI 1.67	FH 0.67	GT&E	WTCI 2.12	AT&T 2.32	WU 2.18	Canada
Number of E.S.	9	132	13	22	112	4	159	5	18	
Number of T/R	2	30	13	22	12	4	30	5	7	
Number of RO's	7	102			>100	1*	129		11**	
Satellite Locations W. Longitude ( ) Spare or for Expansion Purposes	100 103 (97)	99 114 (124) (94) (104) (119)	114 (118) 125 (122)	114 (119)	104 115 (124)	Hughes	113 116 (119)	Comsat	116 (95) (102)	88 109
Satellite ARC degrees W. Long.	80-130	2-145	110-150	58-138	70-120	70-120		70-120	70-120	
Satellite E.I.R.P. dBW	33.1 26.0	33	35 26	37.5(4) 46 (12)	36	33	41.6(4) 38.1(12)			
Transponders	24	24	12-14	48	120	8	12	24	36	

* If required.
** Plus MAILOGRAM.

[a]After OTP (1972) and Barmat (1971).

Table 16 (continued)

General System and Earth Station Characteristics[a]

Characteristics	APPLICANTS								
	Hughes	Comsat	RCA	MCI	FH	GT&E	WTCI	AT&T	WU
Transmitter									
Power (Watts)	200/ chan.	630/ chan.	300	3000	12	1000	1000	1000	360
Bandwidth (MHz)	36	34	500 total	36	36	40	40	40	36
Antenna									
Size (Feet)	98	97	60	32		98	60	*95-105	45
Gain (dB) 4 GHz	59.1	59		49.4	59.0		55		54.3
Gain (dB) 6 GHz	62.9	62	59	53.0	62.5	62.5	58.2	62.5	57.8
Beamwidth (degrees) 4 GHz	0.18	0.18		0.54	0.18		0.28	0.18	0.32
Beamwidth (degrees) 6 GHz	0.12	0.12	0.19	0.36	0.12	0.12	0.19	0.12	0.21
Noise Temperature (K)	150	60	72.5	55	60		75	60	
G/T (dB)	36.7	41.2	40.4	38.1	40.9	43	36.2	40.9	35.3
Azimuth of Radiation (degrees)		102-257	225-260			120-240		207-235	98-1
Main Beam (dBW)	83	90	83.8	90.8	73	92	81.5	92.5	83
Horizontal Plane (dBW/4KHz)		18.5	25.8	5		3			

*Three 95-105 ft. antennas.

Not all of the 280 transponders will be used by the CATV industry because of the competitive needs of other industries for transmission of telephone, data, and television signals by satellite. The role of satellites in one-way and two-way television transmission for CATV applications has not been explored on a system basis sufficiently well to permit an assessment. The potential number of channels represents an opportunity for rapid growth in interconnection, but cost will be an important factor.

A final comment relative to the frequency bands of satellite transmission is relevant. The U.S. domestic satellite applications generally propose to use the common carrier frequency bands for downlink transmissions with a few exceptions. In order to transmit in these frequency bands, the satellite radiated power flux density is limited to prevent interference to terrestrial microwave systems. Research is needed to develop terminals which can operate in frequency bands above 10 GHz, which are less restrictive in terms of radiated power flux density. An important future possibility exists in the use of digital television transmission for broadcasting (see section 5.3).

5.2. Line-of-sight Transmission

Microwave transmission below 15 GHz uses repeater spacings on the order of 15-40 miles. Diversity operation provides reliable operation since rain attenuation is low (25 mm/hour rain rate: 0.09 dB/km at 6 GHz and 0.75 dB/km at 11 GHz). Above 15 GHz the rain attenuation forces repeater spacings to 1.5 to 4 miles and perhaps as long as 10 miles (25 mm/hour rain rate: 7.5 dB/km). Attenuation measured at 60 GHz appears to be greater than anticipated according to Roche (1970).

As previously mentioned in section 3, common carrier microwave transmissions occur in bands around 4, 6, and 11 GHz. Allocations in the 10-13 GHz band are listed in table 17. A number of manufacturers offer equipment in these bands. Morgan et al. (1972) observe that 16,620 radio-relay allocations exist in the 3.700-4.200 GHz band, 11,820 allocations exist in the 5.925-6.425 GHz band, and about 4,500 allocations have been made in the 6.625-7.125 GHz band.

Most of the equipment in the 10.55 to 13.25 GHz band uses low index FM as the modulation. Low index FM enjoys no significant signal-to-noise ratio advantage relative to DSB-AM, but does allow the use of non-linear microwave amplifiers (TWT). The absence of linear microwave power

amplifiers may be changing with recent developments at 4 GHz (Seidel, 1971). SSB-AM transmission effectively uses one-half the low index FDM-FM signal bandwidth and permits heterodyne translation to standard television frequencies without demodulation to baseband and re-modulation.

Table 17
Allocation from 10.55 to 13.25 GHz

FCC Rules Part	FREQUENCY BAND	DESIGNATOR	SERVICE	MAX OUTPUT POWER (Watts)
87,89,91	10.55 - 10.68	25,000 F9	Business Radio	1.5
21	10.70 - 11.70	30,000 F9	Common Carrier	1.5
81,87,89 91,93	12.20 - 12.70	20,000 F9	Misc. Private Business Radio	1.0
74	12.70 - 12.95	25,000 F9*	CATV/CARS	1.0
73	12.70 - 13.25	25,000 F9	Aux. Broadcast	1.0
21	13.20 - 13.25	25,000 F9	Common Carrier	1.0

*AM is also permitted in the CARS band

However, as promising as SSB-AM systems appear, they are in an early stage of development, and the few real systems in existence, particularly all solid state, are still in an experimental or brassboard stage (Maccone, 1972; Ivanek, 1972). One of the problems, as mentioned before, in the development of SSB-AM is in transmitter linearity (Ivanek, 1972). Various schemes have been experimented with and simple, but adequate, solutions have yet to be found. One experimental system (Ivanek, 1971), as an example, shows

launch in April of 1973. These channels are available for lease to United States Corporations on a temporary basis. RCA has made an agreement to use one channel of ANIK 2 starting in June 1973. The American Satellite Corporation (AMSAT), a joint venture between Fairchild Industries and Western Union International, has agreed to lease two channels for one year. Other leases are expected in the near future by U.S. corporations which have proposed a U.S. Domestic Satellite System. Lease costs per channel are estimated at $2.5 million per year. These costs are consistent with those used in section 3. These satellites represent an opportunity to develop a pilot CATV television experiment within the limitations of the satellite antenna coverage patterns.

Proposals for the U.S. Domestic Satellite Systems are somewhat difficult to summarize accurately since they are in a state of change. Initial proposals totaled about 600 transponders in orbit with each transponder capable of one color TV broadcast or about 900 to 1000 FDM/FM voice channels or a 34 Mbps data stream. One notes from the digital versus analog discussion in section 5.3 that over five monochromatic digital television signals might be multiplexed in the 34 Mbps data stream in the future.

Table 15 gives a general summary of the proposed system characteristics. Table 16 summarizes individual system parameters including total system investment cost estimates and per channel space segment cost estimates.

Use of satellite circuits in television and data transmission for CATV applications was discussed in section 3, including cost estimates. At the time of this report, eight applications* to build domestic satellite systems are pending before the FCC (Wall Street Journal, 1972). A current restriction limits A.T.&T. to use satellites for regular and wide-area or WATS telephone service and to provide private-line communications to the federal government. These restrictions will terminate in three years after A.T.&T. offers satellite service. It appears from table 16 that the eight applications involve on the order of 280 transponders. Each transponder is designed to relay one color television signal using high index FM when television signals are to be relayed.

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*A.T.&T. and Comsat; Comsat and Lockheed Aircraft Corp. and MCI Communications Corp.; Western Union Telegraph Co.; Western Telecommunications, Inc.; Fairchild Industries, Inc.; RCA Global Communications, Inc.; RCA Alaska Communications, Inc.; Hughes Aircraft Co.; and GTE Service Corp. (see also Barmat, 1971). Fairchild Industries and Western Union International, Inc. have formed the American Satellite Corp. as a joint venture and recently announced purchase of three 12-transponder communication satellites (Wall Street Journal, 1973).

Table 15

General Summary: U.S. Domestic Satellite System Characteristics

Transmitter Power	- 12 watts to 3kW	
Transmitter Bandwidth	- 34 to 40 GHz	
Antenna Size	- 32 to 105 feet	
Antenna Gain	- 4 GHz	54.3 to 59.4 dB
	6 GHz	57.8 to 62.9 dB
Antenna Beamwidth	- 4 GHz	0.18 to 0.32 degrees
	6 GHz	0.12 to 0.21 degrees
Noise Temperature	- 60 to 150 degrees K	
G/T	- 35.3 to 41.2 dB	
Azimuth of Radiation	- 102 to 265 degrees	
E.I.R.P. Main Beam	- 73 to 92.5 dBW	
E.I.R.P. Horizontal Plane	- 3 to 25.8 dBW/4 kHz	

Table 16

General System and Earth Station Characteristics[a]

Total System Investment $ x 10^6	82.6	248.4	197.7	229.4	210.8		67.7	241.4	94.6	
Per Channel $ x 10^6 Space Segment Investment	Hughes 1.78	Comsat 2.32	RCA 2.02	MCI 1.67	FH 0.67	GT&E	WTCI 2.12	AT&T 2.32	WU 2.18	Canada
Number of E.S.	9	132	13	22	112	4	159	5	18	
Number of T/R	2	30	13	22	12	4	30	5	7	
Number of RO's	7	102			>100	1*	129		11**	
Satellite Locations W. Longitude ( ) Spare or for Expansion Purposes	100 103 (97)	99 114 (124) (94) (104) (119)	114 (118) 125 (122)	114 (119)	104 115 (124)	Hughes	113 116 (119)	Comsat	116 (95) (102)	88 109
Satellite ARC degrees W. Long.	80-130	2-145	110-150	58-138	70-120	70-120		70-120	70-120	
Satellite E.I.R.P. dBW	33.1 26.0	33	35 26	37.5(4) 46 (12)	36	33	41.6(4) 38.1(12)			
Transponders	24	24	12-14	48	120	8	12	24	36	

* If required.
** Plus MAILOGRAM.

[a]After OTP (1972) and Barmat (1971).

Table 16 (continued)

General System and Earth Station Characteristics[a]

Characteristics	APPLICANTS								
	Hughes	Comsat	RCA	MCI	FH	GT&E	WTCI	AT&T	WU
Transmitter									
Power (Watts)	200/ chan.	630/ chan.	300	3000	12	1000	1000	1000	360
Bandwidth (MHz)	36	34	500 total	36	36	40	40	40	36
Antenna									
Size (Feet)	98	97	60	32		98	60	*95-105	45
Gain (dB) 4 GHz	59.1	59		49.4	59.0		55		54.3
Gain (dB) 6 GHz	62.9	62	59	53.0	62.5	62.5	58.2	62.5	57.8
Beamwidth (degrees) 4 GHz	0.18	0.18		0.54	0.18		[illegible]	0.18	0.32
Beamwidth (degrees) 6 GHz	0.12	0.12	0.19	0.36	0.12	0.12	[illegible]	0.12	0.21
Noise Temperature (K)	150	60	72.5	55	60		75	60	
G/T (dB)	36.7	41.2	40.4	38.1	40.9	43	36.2	40.9	35.3
Azimuth of Radiation (degrees)		102-257	225-260			120-240		207-235	98-1
Main Beam (dBW)	83	90	83.8	90.8	73	92	81.5	92.5	83
Horizontal Plane (dBW/4KHz)		18.5	25.8	5		3			

*Three 95-105 ft. antennas.

Not all of the 280 transponders will be used by the CATV industry because of the competitive needs of other industries for transmission of telephone, data, and television signals by satellite. The role of satellites in one-way and two-way television transmission for CATV applications has not been explored on a system basis sufficiently well to permit an assessment. The potential number of channels represents an opportunity for rapid growth in interconnection, but cost will be an important factor.

A final comment relative to the frequency bands of satellite transmission is relevant. The U.S. domestic satellite applications generally propose to use the common carrier frequency bands for downlink transmissions with a few exceptions. In order to transmit in these frequency bands, the satellite radiated power flux density is limited to prevent interference to terrestrial microwave systems. Research is needed to develop terminals which can operate in frequency bands above 10 GHz, which are less restrictive in terms of radiated power flux density. An important future possibility exists in the use of digital television transmission for broadcasting (see section 5.3).

5.2. Line-of-sight Transmission

Microwave transmission below 15 GHz uses repeater spacings on the order of 15-40 miles. Diversity operation provides reliable operation since rain attenuation is low (25 mm/hour rain rate: 0.09 dB/km at 6 GHz and 0.75 dB/km at 11 GHz). Above 15 GHz the rain attenuation forces repeater spacings to 1.5 to 4 miles and perhaps as long as 10 miles (25 mm/hour rain rate: 7.5 dB/km). Attenuation measured at 60 GHz appears to be greater than anticipated according to Roche (1970).

As previously mentioned in section 3, common carrier microwave transmissions occur in bands around 4, 6, and 11 GHz. Allocations in the 10-13 GHz band are listed in table 17. A number of manufacturers offer equipment in these bands. Morgan et al. (1972) observe that 16,620 radio-relay allocations exist in the 3.700-4.200 GHz band, 11,820 allocations exist in the 5.925-6.425 GHz band, and about 4,500 allocations have been made in the 6.625-7.125 GHz band.

Most of the equipment in the 10.55 to 13.25 GHz band uses low index FM as the modulation. Low index FM enjoys no significant signal-to-noise ratio advantage relative to DSB-AM, but does allow the use of non-linear microwave amplifiers (TWT). The absence of linear microwave power

amplifiers may be changing with recent developments at 4 GHz (Seidel, 1971). SSB-AM transmission effectively uses one-half the low index FDM-FM signal bandwidth and permits heterodyne translation to standard television frequencies without demodulation to baseband and re-modulation.

Table 17
Allocation from 10.55 to 13.25 GHz

FCC Rules Part	FREQUENCY BAND	DESIGNATOR	SERVICE	MAX OUTPUT POWER (Watts)
87,89,91	10.55 - 10.68	25,000 F9	Business Radio	1.5
21	10.70 - 11.70	30,000 F9	Common Carrier	[illegible].5
81,87,89 91,93	12.20 - 12.70	20,000 F9	Misc. Private Business Radio	1.0
74	12.70 - 12.95	25,000 F9*	CATV/CARS	1.0
73	12.70 - 13.25	25,000 F9	Aux. Broadcast	1.0
21	13.20 - 13.25	25,000 F9	Common Carrier	1.0

*AM is also permitted in the CARS band

However, as promising as SSB-AM systems appear, they are in an early stage of development, and the few real systems in existence, particularly all solid state, are still in an experimental or brassboard stage (Maccone, 1972; Ivanek, 1972). One of the problems, as mentioned before, in the development of SSB-AM is in transmitter linearity (Ivanek, 1972). Various schemes have been experimented with and simple, but adequate, solutions have yet to be found. One experimental system (Ivanek, 1971), as an example, shows

rate (baseband signal) would be 6.72×10^6 bits per second. Conventionally, picture coding compression ratios are expressed in a different way, as explained below, although the concepts are similar. Further, in many techniques, the quantizing, encoding, and compression are performed simultaneously so that the signal processing explained in terms of PCM is not actually present. The digitally encoded and compressed data sequence has no resemblance to a picture structure unless the decompression-decoding algorithm is used.

Finally, it is noted that each method of quantizing an analog signal has a certain usable dynamic range for the input signal. Uniformly quantized PCM, for example, for $n = 8$ does not have sufficient dynamic range to digitize voice or video signals. Non-linear quantized PCM (referred to as companded PCM) is usually employed to obtain an adequate dynamic range to match the input signal dynamic range. Companding techniques have also been developed for delta modulation.

The state-of-the-art in reducing the data rate or bandwidth is reflected in Bell Laboratories publications (Mounts, 1970); special IEEE issues (IEEE Transactions on Communication Technology, 1971; IEEE Proceedings, 1967 and 1972; IEEE Spectrum 1972; and IEEE Transactions on

Computers, 1972), and numerous survey papers such as Schwartz (1969), Huang et al. (1971), and Wilkins et al. (1971). A relatively up-to-date bibliography is available from the Image Processing Laboratory at the University of Southern California (Andrews,1972) This bibliography contains approximately 1000 references on the subject of image processing, coding, and transmission. Some textbooks are also available (Rosenfeld, 1971; Lawrence, 1967; and Berger, 1971). The consensus at the present time indicates data rates of 1 x 10^6 bits per second for 30 frames per second, good quality gray scale video transmission for Bell System PicturePhone* television signals. Recent developments presented at the 1973 Picture Coding Conference indicate Bell System plans for a 1.544 Mbps Picturephone* digital transmission data rate for network applications including T1 carrier. The single video channel encoder uses frame-to-frame redundancy encoding with Shannon-Fano variable code word lengths. A 345,000 bit frame memory and a 120,000 bit coder buffer are included.

The 525 line broadcast television picture, as noted previously, has 270,000 picture elements per frame. This is not $(525)^2$ because of the 4:3 picture aspect ratio and other resolution factors. At a 30 frames per second rate about

*Registered Trademark of A.T.&T.

8.1×10^6 picture elements per second are obtained. Connor et al. (1972) summarize intra-frame coding techniques and the number of transmitted bits per picture elements as:

fixed length code with predictive algorithm	3-4 bits per picture element ($2.43 - 32.4 \times 10^6$ bps)
Variable length code with predictive algorithm	2-3 bits per picture element ($16.2 - 24.3 \times 10^6$ bps)
Adaptive techniques Conner, et al. (1972)	1.2-2.2 bits per picture element ($9.72 - 17.8 \times 10^6$ bps)
Transform techniques (2 dimensional, adaptive) Wintz (1972)	1-2 bits per picture element ($8.1 - 16.2 \times 10^6$ bps)

It is important to note that the statement 1-2 bits per picture element is the result of dividing the $8.1 - 16.2 \times 10^6$ bps data rate by 270,000 picture elements. It is an average and does not mean that each picture element requires 1-2 bits. Some picture elements need more and some less.

Inter-frame coding described by Haskell et al. (1972) achieves a 1 bit per picture element average rate with a 67,000 bit buffer required for overflow. Ignoring the forced updating of picture information due to buffer

overflow, the long-term average data rate is about 0.35 bits per picture element. Buffer size and delay make it difficult to achieve this rate with a single channel. If data from several (12-15) conditional-replenishment coders are combined prior to buffering and transmission, the required channel rate appears to be about 0.5 bits per picture element. This would involve a data rate of about 4.1×10^6 bits per second for each video picture signal using black and white rather than color techniques. For color transmission the data rate would be around 10×10^6 bits per second. These rates actually apply only to the head-and-shoulders picture of the Picturephone* application.

The CATV system will be assumed to use 5 MHz bandwidth for the television video signal. Also, a signal-to-noise ratio of 42 dB to 48 dB at the television receiver is assumed as well as excellent phase stability because of color transmission. This type of communications channel can support an 8 level coherent PSK modulation for transmission on the cable or for interconnection. Assuming a required bit error rate of 1×10^{-6} (4 bit errors per second) for good picture quality, a signal-to-noise ratio of 19 to 20 dB is needed. The signal bandwidth for the 4.1×10^6 bps rate would be between 1.4 MHz and 2.8 MHz (Hill, 1972). One

*Registered A.T.&T. Trademark

could then ideally transmit two or three digital television black and white video channels for every analog television video signal as long as the Picturephone* picture statistics are applied. For color, larger bandwidths would be needed. This would represent the current research and development state-of-the-art for digital Picturephone* television. A key unanswered question in this area concerns the memory size for commercial television pictures. The numbers presented above are based only on a head-and-shoulders type picture. The savings in signal-to-noise ratio is substantial and represents an area for trade off with the required digital equipment and buffers for data compression.

Analog transmission is characterized by an accumulation of noise which gradually degrades the signal-to-noise ratio irreversibly. Operation of IF amplified microwave links with diversity and 80 dB signal-to-noise ratio does permit coast-to-coast video transmission. Digital transmission accumulates errors during regeneration because of noise exhibited partly as clock jitter, but the degradation is reversible with error correction coding. Monitoring and fault location are easier, but degradation exhibits a threshold effect. If time division multiplex transmission

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*Registered A.T.&T. Trademark

is used, timing and synchronization requirements impose added costs and error sources.

From the point of view of CATV interconnection and to some extent within the larger CATV systems, digital transmission may be a feasible alternative in the future. An 80 video channel interconnection loop may be able to operate at less than 400 Mbps data rate in a bandwidth less than 200 MHz for black and white transmission. This bandwidth is within the capabilities of coaxial cable, microwave radio, and satellite relay. A digital loop network configuration would provide point-to-point CATV system interconnection with far less interconnecting links and also would give 24-hour full channel service without switching. It appears that investigation of the application of this technology to CATV systems would be fortuitous at the present time. Most of the CATV systems must be built and changes can be made much easier in the next few years.

5.4. Queueing Aspects

Those services proposed for CATV two-way systems which involve request-service interactions in real time face a significant system trade-off. The system capacity can be developed to handle all requests with no delay. This design approach must be responsive to maximum peak loads.

To minimize capacity requirements, one can introduce the concept of waiting times for access and service. If acceptable delays (to the customer) can be found, one can determine the required capacity for efficient utilization of the system resources. The familiar application of these ideas is found in the selection of the number of checkout counters to install in a supermarket store.

Martin (1971) describes two examples which illustrate the principles involved. A CATV system with 30,000 subscribers is assumed. One television channel is assumed to be connected in a loop and operated as a 6 Mbps data channel. The channel would be operated to collect data from subscriber sets. Using a block framing technique to include synchronization bits and error correcting parity check bits, a data rate of 15.8 characters per second from each subscriber set can be maintained. One must type very fast indeed to maintain this rate. Maximum delay would be 63 milliseconds. Other polling designs could be developed to obtain the same delay as an average delay and allow the system to serve more subscribers or serve the same number of subscribers with a smaller data rate. The capability of a television channel bandwidth for interrogation of 30,000 or more subscribers is apparent.

Martin (1971) also describes an example in which data is

transmitted to the subscribers. Again a single television channel is used for a 6 Mbps data rate and 30,000 subscribers are assumed. The television set is assumed to display the character responses of 119 characters each. Average access delays would be 0.25 second with a maximum possible access delay of 4 seconds. This may be satisfactory since more than 4 seconds are usually required to read 119 characters.

These examples involve transmission of request data and reply data in block form on a loop circuit in which the head-end or terminal wait for the next addressed block for transmission. Conventionally this time of transmission is referred to as the service time with the average designated μ^{-1}. The average rate of transmission per hour is designated as λ. The product $\lambda\mu^{-1}$ is ρ. This reflects the channel utilization or the efficiency of use of the system resources.

A review of proposed services indicates each will have a different distribution of service times and consequently different average service times μ^{-1} Further, a multiple number of channels will be available for transmission of services. These problems are difficult to treat analytically without simulation. Some general estimates can be made. Using results of Janc et al. (1973) and

Thomopoulos et al. (1973), a three television channel case is assumed.

The system has one head-end and one television channel for receiving requests from subscribers, as described before. The system has 30,000 subscribers. Three television channels are available for servicing the requests, i.e., transmitting the information requested to the subscriber terminal. When a transmission occurs on a channel to service a request, that channel is not available to service any other subscribers request until the first transmission has been completed. The head-end has three identical sets of equipment for servicing requests. When a request is received, the transmission occurs on one of the available channels and the subscribers television set is tuned to the appropriate channel automatically.

Figure 16 shows the relation between ρ, μ^{-1} and λ for two different grades of service. The grade of service is the probability that all three channels are busy when a subscriber makes a request. This is the system access probability if it is assumed that the request channel has zero delay. Since that delay is a maximum of 63 milliseconds here, it will be neglected. When a subscriber encounters a delay, the next important parameter describes the average waiting time to access. This is given by a

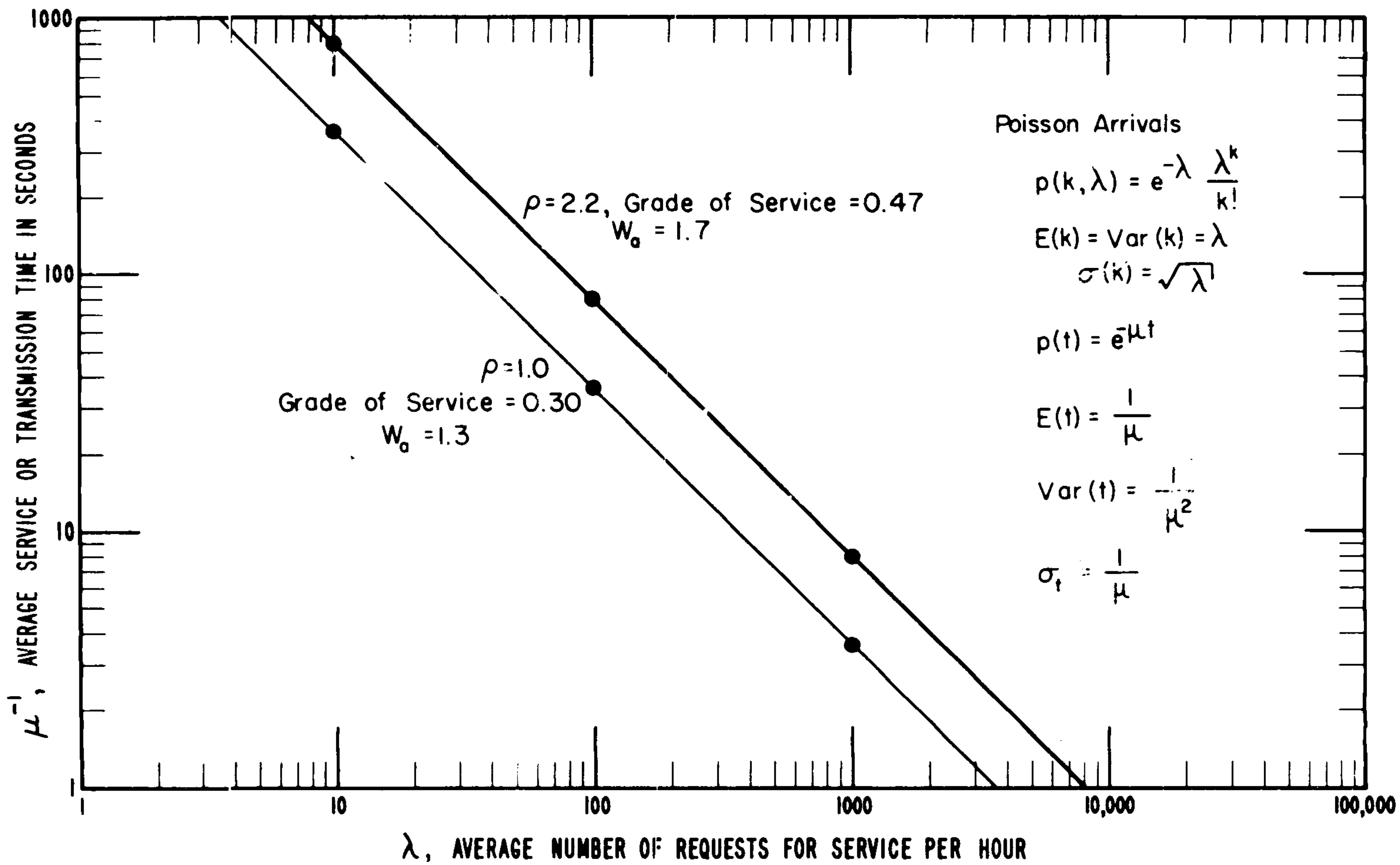

Figure 16. Grade of service and waiting time factor for a 3 channel system.

multiplication factor expressed as W_a. The average waiting time is then given by μ^{-1} times W_a.

In figure 16, $\rho = 1.0$ corresponds to an average utilization of only one channel whereas $\rho = 2.2$ reflects an average utilization of two full channels and the third channel 20 percent of the time. The rate of requests for service λ is given in the number per hour. For $\rho = 1.0$, the grade of service is 0.30 and the waiting time factor W_a is 1.3. When $\rho = 2.2$, the grade of service increases to 0.47 and the waiting time factor increases to 1.7. In the latter case a subscriber would encounter a delay almost one-half the time and the average delay to transmit his request would be 1.7 times the value of μ^{-1}.

By extrapolation from figure 16 along the $\rho = 2.2$ curve, one obtains μ^{-1} of 0.25 seconds for 30,000 requests per hour and μ^{-1} of 0.8 seconds for 10,000 requests per hour. The 30,000 requests would correspond to a peak load and 10,000 requests to 33 percent load. The corresponding average delays would be 0.43 seconds and 1.4 seconds. The 30,000 subscriber case gives the same results as Martin's (1971) second example, cited previously. The μ^{-1} of 0.25 seconds corresponds to about 120 characters average per service response. This may be adequate for many time-share

channel systems have to be developed, a 30 channel system of 30,000 subscribers may be able to service 8,000 requests per hour with an average service time of 10 seconds and an average waiting time of 17 seconds for the 47 percent of the requests which would be delayed. One notes that 53 percent of the requests would not encounter any delay.

These examples suggest that a large number of television channels may be needed to support interactive two-way services for large CATV systems. This appears to be the case for an aggregation of multiple services. Some of these could be fairly sophisticated and involve large values of μ^{-1} (such as 10 minute duration travel films). The model used for figure 16 involves a Poisson arrival process with the same exponential service time distribution on each channel. Situations with interactive service times require a model such as that described by Matney (1972). Other models used in computer time-share system design may be appropriate (Martin, 1967).

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The interconnection of existing and future CATV systems for two-way transfer of audio/video and digital data signals has been surveyed. The concept of interconnection is explored relative to existing and proposed CATV systems and broadband teleservice networks, common carrier services, facilities and growth projections, and the technical-economic state-of-the-art of the required technology. The need for interconnection is reviewed. Satellite and line-of-sight microwave transmission in addition to digital versus analog transmission systems aspects are considered in terms of interconnection. Some potentially significant queueing problems are identified.

16. Key words *(Alphabetical order, separated by semicolons)*

Key words: broadband cable system queueing; Cable Television; CATV; common carrier services; interconnection; satellite television distribution; teleservices

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